2011

Impact of the MON89788 event for glyphosate tolerance on agronomic and seed traits of soybean and molecular characterization of the mutant fap3(A22) allele for reduced palmitate concentration in soybean

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Impact of the MON89788 event for glyphosate tolerance on agronomic and seed traits of soybean and molecular characterization of the mutant *fap3*(A22) allele for reduced palmitate concentration in soybean

by

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A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Plant Breeding

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Iowa State University

Ames, Iowa

2011

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CHAPTER 1

INTRODUCTION

Glyphosate is a widely used herbicide for weed control in soybean [*Glycine max* (L.) Merr.] and other crops. The chemical disrupts the shikimate pathway in plants. Without this pathway, plants cannot produce some essential amino acids and secondary metabolites, which causes plant death (Jaworski, 1972). The release of glyphosate-tolerant (GT) soybean cultivars by Monsanto in 1996 made it possible for farmers to use post emergent applications of glyphosate to manage weeds (Padgette et al., 1995). Tolerance was obtained by introduction of a *cp4 EPSPS* gene from *Agrobacterium* sp. strain CP4 into a soybean line. This transgene, referred to as Roundup Ready® event 40-3-2, encodes for a CP4 EPSPS enzyme that allows the shikimate pathway to proceed even when glyphosate is applied (Padgette et al., 1995).

The Monsanto Co. developed a second transgenic event, MON89788, with the *cp4 EPSPS* gene that has been named Roundup Ready 2 Yield®. The MON89788 event was created to enhance the yield capabilities of GT soybean cultivars while maintaining weed control practices with glyphosate (Meyer et al., 2006). A primary concern for the soybean breeder when utilizing a novel gene for any trait is the influence it may have on agronomic and seed traits of cultivars (Elmore et al., 2001). The first objective of my research was to evaluate the impact of the MON89788 transgene on seed yield and other agronomic traits in comparison with conventional lines that are glyphosate-susceptible (GS).

Reduction of the palmitate concentration in soybean oil is desirable for reducing the amount of saturated fat in the human diet (Hu et al., 1997). Chemical mutagenesis was used to develop the line A22 with the mutant allele designated *fap3*(A22) that reduces palmitate concentration in the seed oil (Fehr et al., 1991). The second object of my research was to determine the molecular basis of the *fap3*(A22) mutation and develop a corresponding molecular marker to assist in future efforts for developing soybean cultivars with low saturated fat.

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LITERATURE REVIEW

Importance of Glyphosate and Glyphosate-Tolerant Soybeans

The Roundup™ herbicide was released by the Monsanto Co. in 1974 (Franz, 1976). The active ingredient in Roundup is glyphosate (N-(phosphonomethyl)glycine). Glyphosate is a non-selective, foliar applied herbicide that allows applicators to kill all living plants at the time of application. The translocation of glyphosate throughout the plant provides effective control of hard to kill perennial weeds that may contain rhizomes or tubers because their root tissues are exposed to the herbicide. Glyphosate strongly binds to soil particles, which reduces the risk of leaching. Carryover of glyphosate is not a concern because microbial activity within the soil quickly degrades the compound (Rueppel et al., 1977). This allows users to sow seed of a crop shortly after glyphosate has been applied as a weed control measure. The herbicide has a low acute oral toxicity and does not pose a serious health risk to mammals if ingested, but skin irritation can occur (Weed Science Society of America, 1983). All of these properties make glyphosate a useful herbicide for eliminating weeds with minimal risk (Tomlin, 1994).

The application of glyphosate on soybean cropping systems accounted for over 75% of all herbicide applications on soybeans in 2006 (Bonny, 2009). This was due to the introduction of glyphosate-tolerant (GT) soybean cultivars in 1996 (Padgette et al., 1995a). Glyphosate applications on GT cultivars can effectively control weeds without damaging the soybeans (Elmore et al., 2001a). GT soybeans were grown on 93% of the soybean acreage in the United States in 2009 (Economics Research Service, USDA, 2010). The benefits of GT soybeans that may be realized by the farmer include improved weed control, yield, and net income compared with conventional soybean cultivars (Wait et al., 1999)

Glyphosate Mode of Action

Glyphosate interrupts the shikimate pathway in plants. With this metabolic process inhibited plants cannot synthesize aromatic amino acids (Jaworski, 1972). The aromatic amino acids phenylalanine, tryptophan, and tyrosine are three of the 20 essential amino acids in plants that can be further metabolized to form products such as auxins, anthocyanins, alkaloids, tocopherols, ubiquinone and lignins (Franz et al., 1997). The shikimate pathway can accumulate up to 50% of the dry matter weight of some plants (Heldt, 2005).

The shikimate pathway is a seven step metabolic process that ends with the formation of chorismate that can be used to form aromatic amino acids or other plant secondary metabolites (Weaver and Herrman, 1999). The sixth step of the shikimate pathway utilizes shikimate 3-phosphate (S3P), formed during the fifth step, and phosphenol pyruvate to form 3-enolypyruvylshikimate 3-phosphate (EPSP). This step is carried out by 5-enolpyruvylshikimate 3-phosphate synthase (EPSPS) (Weaver and Herrman, 1997). The last step takes a phosphate group off of EPSP to form chorismate.

EPSPS has been shown to be the enzyme that binds glyphosate and inhibits the shikimate pathway (Steinrücken and Amrhein, 1980). Glyphosate is tightly bound to an EPSPS-S3P complex in the place of PEP and does not readily disassociate from the complex. Glyphosate is considered a potent competitive inhibitor of PEP (Sikorski, 1997). This prevents PEP from reacting with EPSPS and does not allow the shikimate pathway to proceed (Franz et al., 1997; Schönbrunn et al., 2001). Without the shikimate pathway producing aromatic amino acids and many plant secondary metabolites, the plant will die.

Development of Glyphosate-Tolerant Soybean

The favorable chemical and environmental characteristics of glyphosate led to research on ways to genetically engineer crop plants to make them tolerant to the herbicide for post-emergent weed control in crop fields. Three methods of glyphosate tolerance have been explored: over-expression of the sensitive enzyme in the shikimate pathway, introducing a way for the plant to metabolize glyphosate, and incorporating a glyphosate-insensitive enzyme in the plant to allow the shikimate pathway to proceed normally (Widholm et al., 2001).

The method used to develop GT soybean cultivars was introducing an insensitive enzyme into the plant (Barry et al., 1997). An *Agrobacterium* sp. strain CP4 that contains an EPSPS enzyme that does not bind glyphosate and has a high affinity for PEP was first reported in 1992 (Barry et al., 1992). Researchers at the Monsanto Co. cloned the *cp4 EPSPS* gene into *Escherichia coli* and studied its expression in the presence of glyphosate (Padgette et al., 1995b). The ability for microorganisms to grow in the presence of glyphosate when containing the *cp4 EPSPS* showed that this gene allowed organisms to be tolerant to glyphosate.

The first GT soybean event used commercially was designated as 40-3-2 (Padgette et al., 1995a). Cultivars that contained the transgene were referred to as Roundup Ready™. The DNA construct used for the soybean transformation that led to 40-3-2 included the *cp4 EPSPS* gene, a chloroplast-transit peptide, a 35S promoter sequence from cauliflower mosaic virus (CaMV) and a 3′ untranslated region from the napoline synthase gene (Padgette et al., 1995a). Attaching a chloroplast-transit peptide from *Petunia hybrida* to the 5′ end of the gene allowed its enzyme product to be transported to the chloroplast and be present at the site of the shikimate pathway (Della-Cioppa et al., 1986). The CaMV 35S promoter is effective at increasing the transcription levels of foreign genes in plants (Franz et al., 1997). The 3′ untranslated region attaches a polyadenylate tail to the mRNA sequence of the *cp4 EPSPS* gene (Barry et al., 1997). This gene construct was fused into the plasmid vector PV-GMGT04. Particle acceleration of the construct into the soybean line A5403 was the source of lines that were evaluated for glyphosate tolerance (Padgette et al., 1995a). Progeny from the R_0 regenerated plants were evaluated and a line (event) designated 40-3-2 had stable inheritance of the *cp4 EPSPS* gene. The transgene was inherited as a single dominant allele (Padgette et al., 1995a).

Molecular characterization of the CP4 EPSPS enzyme defined the mechanism by which glyphosate does not bind to the mutant EPSPS enzyme in GT-tolerant soybean cultivars with the 40-3-2 event (Funke et al., 2006). An alanine residue at the 100 position of the amino acid sequence is present near the active site of glyphosate binding in the CP4 EPSPS enzyme. In wild-type plants that are susceptible to glyphosate, the EPSPS enzyme has a glycine at this position. The methyl group in the alanine residue side chain interferes with the binding site of glyphosate and reduces the affinity of glyphosate for the CP4 EPSPS enzyme. This allows for the mutant EPSPS to function in the shikimate pathway of the plant and normal plant growth to occur.

The line 40-3-2 and lines derived from it were evaluated by Delannay et al. (1995) to determine the effect the transgene on yield and other important agronomic and seed traits. They found no difference in yield between lines that contained the *cp4 EPSPS* gene and lines that did not contain the gene. However, subsequent research by Elmore et al. (2001b) compared GS and GT sister lines. This research showed that a yield loss of up to 5% can occur in GT cultivars from the gene or gene insertion process.

The Roundup Ready 2® Yield Trait

The development of another GT soybean event by Monsanto was done to enhance the yield capabilities of GT soybean lines while maintaining tolerance to glyphosate for effective weed control (Meyer et al., 2006). Transformation of the soybean cultivar A3244 resulted in the MON89788 event that contained the *cp4 EPSPS* gene coding sequence. An identical nucleotide sequence of the *cp4 EPSPS* gene used in the 40-3-2 event also was used for this transformation (Malven, 2006). However, there were five important differences between the construct used for MON89788 and the one used for 40-3-2. (1) A CTP2 transit-peptide from *Arabidopsis thaliana* was used instead of the *P. hybrida* peptide. (2) A 35S promoter from Figwort Mosaic Virus was used instead of the 35S CaMV promoter. (3) An E9 3′ untranslated sequence from ribulose-1, 5-biophosphate carboxylase small subunit from *Pisum sativum* was used to attach the polyadenylate tail instead of the napoline synthase gene. (4) The DNA construct was put in the PV-GMGOX20 plasmid for transformation instead of a PV-GMGT04 plasmid. (5) Transformation was performed according to the method described by Martinell et al. (2002) instead of the method used by Christou et al. (1988). These five differences led to a unique GT event that was identified as MON89788.

Monsanto researchers performed southern blot analyses of MON89788 across multiple generations to ensure the absence of plasmid backbone sequences, generational stability of the insert, and *cp4 EPSPS* cassette integrity (Meyer et al, 2006). These analyses indicated that the proper genetic elements were inserted and no backbone sequences were present in the soybean genome. Analyses of the number of plants killed from glyphosate application of the R_1 and R_2 generations indicated that there was a single chromosomal insertion of the *cp4 EPSPS* gene. The GT trait in MON89788 is inherited as a single dominant allele.

Importance of Reduced Linolenate Soybean Oil

For my study, the MON98788 transgene was backcrossed from a donor line licensed from the Monsanto Co. into three cultivars that produce an oil with about 1% linolenate compared with about 7% of the fatty ester in conventional cultivars.

Linolenate has been shown to be the main contributor to the lack of oxidative stability and resultant off-flavors of soybean oil (Dutton et al., 1951). To improve its stability and flavor, soybean oil has been hydrogenated to remove the double bonds at the 12-C and 15-C positions in the carbon chain of the fatty ester (Dutton, 1963). This hydrogenation process makes the oil more oxidatively stable, but results in the formation of *trans*-fatty acids that have been linked to the risk of coronary heart disease (Hu et al., 1997). Hydrogenation can create up to 48% *trans*-fatty acids in the oil (Mounts et al., 1994).

Research has been conducted since 1952 to identify genes in soybean that could be used to lower its linolenate content (White et al, 1961; Kleiman and Cavins, 1982). At Iowa State University, mutagenesis was used to develop the three alleles that control the 1%-linolenate trait in the soybean lines of my study. The first allele identified, *fan1*(A5), was developed by treatment of seeds of the line FA9525 with ethane methanesulfonate (EMS) (Hammond and Fehr, 1983). The allele was found in a line designated as A5 that had ≈ 39 g kg^{-1} linolenate compared with its parent that had ≈ 63 g kg^{-1} linolenate (Hammond and Fehr, 1983). The inheritance of reduced linolenate content in A5 initially was considered to be quantitative with a partial maternal effect (Graef et al., 1988). Further research indicated that a mutant allele at the *Fan* locus resulted in the reduced linolenate content of A5 (Rennie and Tanner, 1991). Byrum et al. (1997) found that the *fan1*(A5) allele was caused by a deletion of the gene encoding a ω-3 fatty acid desaturase and accounted for the reduced linolenate in lines that contained this allele. Bilyeu et al. (2003) determined the sequence of the *fan1*(A5) allele and designated it *GmFAD3a* for *Glycine max* fatty acid desaturase 3 homolog A.

The second allele for reduced linolenate, *fan2*(A23), was developed by treatment of seed of the line FA47437 with EMS (Fehr and Hammond, 1996). The line in which the allele was identified, FA47437EMS, was crossed to A5 and progeny were found that had ≈ 23 g kg^{-1} linolenate (Fehr and Hammond, 1996). Two of the progeny with the reduced linolenate were designated A16 and A17. Fehr et al. (1993) studied the inheritance of A16 and A17 and found that the allele in FA437EMS was independent of the allele in A5. This second allele was designated as *fan2*(A23). A16 and A17 had the genotype *fan*(A5)*fan*(A5)*fan2*(A23)*fan2*(A23). Bilyeu et al. (2006) identified the DNA sequence of the *fan2*(A23) allele. They found that the wild-type and recessive alleles differed by a single nucleotide polymorphism within the *GmFAD3c* gene that changes a cytosine nucleotide (wild type) into a thymine nucleotide (mutant). This mutation changes an essential histidine residue to a tyrosine residue in the primary protein sequence and results in a non-functional enzyme.

The third allele, *fan3*, was developed by EMS treatment of the soybean line A89-144003 (Fehr and Hammond, 1999). The line with the allele, designated initially as A89-144003EMS-81 and later as A26, had ≈ 44 g kg^{-1} linolenate. A26 was crossed with AX5711C04 that contained the recessive gene pairs *fan*(A5) and *fan2*(A23). Progeny were identified from the cross that had only ≈ 15 g kg^{-1}. One of the progeny designated A29 had the genotype *fan*(A5)*fan*(A5) *fan2*(A23)*fan2*(A23) *fan3*(A26)*fan3*(A26). Cultivars derived from A29 with the three recessive alleles were used as parents in my study. Bilyeu et al. (2006) found that the *fan3*(A23) allele in A29 differed from the wild-type allele in conventional cultivars by a single nucleotide polymorphism within the *GmFAD3b* gene that changes a guanine nucleotide (wild type) into an adenine nucleotide (mutant). This mutation causes a frameshift that leads to early termination of the transcript.

Warner and Gupta (2003) investigated the flavor quality and oxidative stability of oil with 1%-linolenate, referred to hereinafter as ultra-low linolenate (ULL). They found that oil with normal levels of linolenate in oil had a fishy odor and flavor to the oil. The ULL oil they evaluated had less fishy flavor than the conventional oil. Warner and Fehr (2008) further examined the effects of modified soybean oil content on flavor and stability. The tortilla chips they fried in normal soybean oil had greater rancid flavor than mid-oleate/1%-linolenate soybean oil and ULL soybean oil. Tortilla chips fried in expeller pressed ULL soybean oil also have been shown to be more stable than expeller pressed soybean oil (Warner, 2009). The desirable qualities of the ULL oil has led to its adoption by the food industry as a replacement for partially hydrogenated soybean oil (DiRienzo et al., 2006).

Importance of Reduced Palmitate Soybean Oil

The saturated fatty acid concentration of soybean oil has shown to increase the risk of coronary heart disease (Hu et al., 1997). Reducing the saturated fatty acid concentration by genetic modification can lead to healthier, more useful soybean oil.

The primary focus of modifying the saturated fatty acid profile has been on reducing the palmitate concentration. The mutant allele *fap1*(C1726) was identified in the line C1726 when seeds of the cultivar Century were treated with EMS (Erickson et al., 1988). This mutant allele decreased the palmitate concentration from ≈ 120 g kg^{-1} to ≈ 86 g kg^{-1}. A natural mutation identified in the line N79-2077 contained a mutant allele named $fap3_{nc}$ that lowered the palmitate concentration to ≈ 60 g kg^{-1} (Burton et al, 1994). The mutant allele *fap3*(A22) was identified in the line A1937NMU-173 when seeds of A1937 were treated with N-nitroso-N-methyl-urea (NMU) (Fehr, 1991). This line was given the designation A22. The *fap3*(A22) mutant allele in A22 lowered the palmitate concentration to ≈ 70 g kg^{-1}. By combining the mutant alleles of A22 and C1726, the palmitate concentration can be lowered to 44 g kg^{-1} (Fehr, 1991).

The formation of triacylglycerols (TAG) that make up soybean oil takes place in the plastids. The majority of the fatty acids in triacylglycerols are 16 and 18 carbons long. This chain length is determined by specific thioesterases within plastids that cleave the fatty acid from the acyl carrier protein (ACP) during synthesis (Hildebrand et al., 2008). The resulting free fatty acid enters the cytosol and is incorporated into membrane lipids or TAG. Two classes of thioesterases are present in soybeans. The fatty acid thioesterase A (FAT A) is responsible for cleaving 18:1 fatty acids. The fatty acid thioesterase B (FAT B) is responsible for cleaving 16:0 and 18:0 fatty acids (Hildebrand et al, 2008). The mutant alleles associated with a decrease in palmitate concentration in soybean seed oil result from mutations in the FAT B enzyme; specifically the 16:0-ACP thioesterase enzyme (16:0-ACP TE) (Wilson et al., 2001). Mutations in this enzyme result in a reduction of 16:0 being released into the cytosol and incorporated into TAG during seed development.

The genomic architecture of soybean has suggested that it is a palaeopolyploid that has undergone two genome duplications (Schmutz et al, 2010). These duplications have resulted in a domesticated soybean species that has 75% of its genes present in more than one copy. The 16:0-ACP TE is an example of a gene that is present with more than one copy. Cardinal et al. (2007) showed that soybean lines that contained the *fap3*$_{nc}$ locus had a deletion in the FATB1a isoform. Other FAT B isoforms are present within the soybean genome that did not show an association with the *fap3*$_{nc}$ allele. It has been shown that the *fap3*$_{nc}$ and the *fap3*(A22) alleles are allelic to each other (Primomo et al., 2002). Because of this, it is possible to predict that the phenotypic differences in palmitate concentration, when the *fap3*(A22) allele is present, are due to mutations within the FATB1a gene.

The development of functional markers for major genes of interest can greatly increase the effectiveness of selecting the intended genotypes in a breeding program (Anderson and Lubberstedt, 2003). The use of functional markers makes it possible to select genotypes with the desired gene(s) in backcrossing programs, which may decrease the time it will take to incorporate genes into elite parents. The characterization of mutations and development of functional markers for important soybean traits has been reported. Lenis et al. (2010) identified a SNP within the gene coding sequence of the *lox2* and *lox3* genes that control the reduction of lipoxygenase enzymes in seeds. Functional co-dominant molecular marker assays were described that allow for a high throughput, efficient genotyping system with the *lox2* and *lox3* genes. The ability to select the heterozygous genotype of both of these genes allows for a backcrossing program to continue in each generation instead of using a generation to self F_1 plants and grow the F_2 seed to find the intended genotype with a phenotypic assay. Gillman et al. (2009) identified a SNP within the *lpa1* and *lpa2* genes responsible for the low-phytate trait. These mutations were exploited to develop a functional co-dominant molecular marker for each gene. Both of these instances take advantage of a functional marker to perfectly associate the intended phenotype with molecular data.

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CHAPTER 2

IMPACT OF THE MON89788 EVENT FOR GLYPHOSATE TOLERANCE ON AGRONOMIC AND SEED TRAITS OF SOYBEAN

ABSTRACT

Glyphosate is a popular herbicide for weed control in fields planted to soybean [*Glycine max* (L.) Merr.] cultivars with a transgene that provides tolerance to the chemical. A transgenic event MON89788, known commercially as Roundup Ready 2 Yield ®, was developed by the Monsanto Co. as an alternative to the event 40-3-2 for glyphosate tolerance in soybean. The objective of our study was to compare the agronomic and seed traits of glyphosate-tolerant (GT) lines and glyphosate-susceptible (GS) lines from populations segregating for MON89788. The transgene was backcrossed into three GS cultivars to develop BC_2 populations. There were 27 GT and 27 GS BC_2F_2-derived lines from each backcross population evaluated at four Iowa environments in 2010. The means of the GT lines were not significantly different from the GS lines in any of the populations for seed yield, lodging score, and palmitate, oleate, and linoleate concentrations. The maximum significant difference between the means of the two types was 0.4 d for maturity date, 2 cm for plant height, 5 mg sd^{-1} for seed weight, and 2 g kg^{-1} for protein, 1 g kg^{-1} for oil, 1 g kg^{-1} for stearate, and 0.2 g kg^{-1} for linolenate concentrations. The significant differences among lines within each type and the overlap in their distributions for all of the traits indicated that it would be possible to select GT or GS lines with comparable performance from populations developed by crossing a GS parent to a GT parent with the MON89788 event.

MATERIALS AND METHODS

Three backcross populations were developed with a GT donor parent licensed from Monsanto that contained MON89788 and three GS cultivars developed by Iowa State University that differed in maturity, IA2079, IA3028, and IA3041. The donor parent was of maturity group 4, while the relative maturity of IA2079 was 2.3, IA3028 was 3.0, and IA3041 was 3.4. The three GS cultivars used as the recurrent parents contained the *fan1*(A5), *fan2*(A23), and *fan3*(A26) alleles that control the production of an oil with 1% linolenate concentration (Fehr, 2007). The initial crosses of the GT parent to each of the three GS parents were made at Illinois Crop Improvement Association (ICIA) research station near Ponce, PR in November 2007 using the GS parent as female.

In January 2008 at ICIA, F_1 seeds from each of the single crosses and seeds of the recurrent parents were planted. The F_1 plants were sprayed with Roundup Ultra® at a rate of 1.68 kg ae ha^{-1} at the first trifoliate stage (V2) (Fehr et al., 1971) and 12 d later to eliminate any individuals produced by accidental self-pollinations. The F_1 seeds of the single crosses and seeds of the recurrent parents also were planted during January 2008 in the greenhouse in Ames, IA. In the greenhouse planting, the F_1 plants were sprayed with Roundup Weathermax® at a rate of 1.68 kg ae ha^{-1} at the V2 stage and 12 d later. The F_1 plants of each cross were used as the male parent for the backcross to the GS cultivar at both locations.

The BC_1F_1 seeds of each cross and seeds of the recurrent parents were planted in the field at the Agronomy and Agricultural Engineering Research Center near Ames in May 2008. There were 38 seeds of the IA2079 backcross population (IA2079BC), 173 seeds of the IA3028 backcross population (IA3028BC), and 207 seeds of the IA3041 backcross population (IA3041BC). The BC_1F_1 plants were sprayed with Roundup Weathermax® at the V2 stage to eliminate individual plants that did not contain MON89788. Individual leaves were harvested from the surviving BC_1F_1 plants to test for the *fan1*(A5), *fan2*(A23), and *fan3*(A26) alleles using the molecular protocols developed by Bilyeu et al. (2006). Marker analysis showed that there were no plants of IA2079BC, nine plants of IA3028BC, and 10 plants of IA3041BC that were homozygous for the three *fan* alleles. There were six plants of IA2079BC, 33 of IA3028BC, and 35 of IA3041BC that were homozygous for two of the three mutant *fan* alleles. Plants that were homozygous for two or three of the *fan* alleles were used as males to obtain BC_2F_1 seeds, with preference given to those plants homozygous for the three alleles. There were 47 BC_2F_1 seeds obtained of IA2079BC, 71 seeds of IA3028BC, and 47 seeds of IA3041BC.

In October 2008, the BC_2F_1 seeds were planted at the research station of 3rd Millennium Genetics (3MG) near Santa Isabel, PR. The BC_2F_1 plants were sprayed with Roundup Ultra® on 7 November and 10 d later to eliminate individuals that did not have MON89788. The BC_2F_1 plants of each population were harvested individually and five individual BC_2F_2 seeds from each were analyzed by gas chromatography as described by Hammond (1991). Three individual plants with > 100 seeds were selected from each population that had five individual seeds with < 15 g kg^{-1} linolenate.

In January 2009, 100 BC_2F_2 seeds from each selected BC_1F_1 plant were sown in separate plots at 3MG near Santa Isabel, PR. The plants were not sprayed with glyphosate. The BC_2F_2 plants within each plot were harvested and threshed individually. A five-seed bulk from each plant was analyzed by gas chromatography. The individual plants from each BC_2F_1 family were ranked for their linolenate content and the 70 with the lowest linolenate that had at least 40 seeds were selected.

In May 2009, a separate experiment for each of the three backcross populations was planted at the Agronomy Farm and the Burkey Farm of the Agronomy and Agricultural Engineering Research Center near Ames. Each experiment of 220 entries included the 70 $BC_2F_{2:3}$ lines from each of three BC_2F_1 families and 10 check cultivars. The 10 entries of checks included two entries of the recurrent parent (IA2079, IA3028, or IA3041), the 1%-linolenate cultivar IA3024, and three cultivars required and provided by Monsanto The Monsanto checks were CSR2252N, CSR2522N, and CSR2682N for IA2079BC; CSR2952N, CSR3231N, and CSR3242N for IA3028BC; and CSR3432N, CSR3752N, and CSR3952N for IA3041BC. All of the CSR checks contained the 40-3-2 event for glyphosate tolerance.

The entries were grown in three replications of a randomized complete-block design. There was one replication at the Agronomy Farm and two replications at the Burkey Farm. The plots were single rows 0.76 m long with a row spacing of 1.02 m and an alley of 1.07 m between the ends of the plots. There were 20 seeds planted in plots of one replication at the Burkey Farm that was used to differentiate lines that were GT, GS, or hemizygous for MON89788. This seeding rate was used to be 95% sure of obtaining at least one GS plant in 11 or more progeny of any $BC_2F_{2:3}$ line that was segregating for MON89788 (Sedcole, 1977). The plots in the replication at each location that was not sprayed with glyphosate were planted with 10 to 20 seeds.

The plots of the replication used to determine the genotype of the $BC_2F_{2:3}$ lines for MON89788 were sprayed with Roundup Weathermax® at the rate of 1.68 kg ae ha^{-1} on 23 June at the V2 stage and 7 d later. The lines were rated as all plants died (GS), all plants lived (GT), or segregating for living and dead plants. The time of maturity for each plot in the two replications not sprayed with glyphosate was recorded. The GS and GT plots were harvested individually with a stationary plot thresher (ALMACO, Nevada, IA). A five-seed bulk from each plant was analyzed by gas chromatography to ensure that all harvested plots were < 15 g kg^{-1} linolenate.

There were 27 GS $BC_2F_{2:4}$ lines and 27 GT $BC_2F_{2:4}$ lines selected for the 2010 experiment from each population based on maturity. Nine GS lines in each of the three BC_2F_1 families were matched with nine GT lines of the same maturity in the same family to minimize the influence of the trait on the results of the 2010 experiment. By choosing the same number of GS and GT lines from each BC_2F_1 family, the genetic background of the two types of lines was considered similar. Each experiment also contained 16 check entries. The checks included two entries of the recurrent parent that was harvested from the Ames 2009 experiment and two entries of the recurrent parent harvested from Puerto Rico in January 2010. The recurrent parent harvested from Puerto Rico was used to ensure that no seed source effect would influence the comparison of the recurrent parent with the BC_3-bulk entries described in the next paragraph. Three check cultivars required and provided by Monsanto were used in each experiment. This seed was taken from plots harvested in the 2009 experiment. These checks included CSR2252N, CSR2522N, and CSR2682 for IA2079BC; CSR2522N, CSR2682N, CSR3242N for IA3028BC; and CSR2952N, CSR3132N, CSR3432 for IA3041BC. After the 27 GS and GT selections of each population were made by matching their maturities, the highest yielding $BC_2F_{2:3}$ lines identified in 2009 that were not included in the 27 selections from each population were entered in the 2010 test to determine their potential value as new cultivars. There were seven entries in IA2079BC, six entries in IA3028BC, and two entries in IA3041BC that were selected based on this criterion.

The rest of the entries in each experiment were made up of bulks of BC_3-derived lines of each population to determine their potential value as new cultivars. There were two BC_3-bulk entries in IA2079BC, three BC_3-bulk entries in IA3028BC, and seven BC_3-bulk entries in IA3041BC. These bulk entries were derived as follows. During November 2008 in Puerto Rico, the BC_2F_1 plants that were used for my experiment were used as the male parent and crossed to the recurrent parent to produce BC_3F_1 seed. In January 2009 in Puerto Rico, BC_3F_1 seeds of each population were planted. Single BC_3F_1 plants were harvested in May 2009. In the summer of 2009, BC_3F_2 plants from each BC_3F_1 plant were grown as families in separate plots. The plots were sprayed with Roundup Weathermax® at the rate of 1.68 kg ae ha^{-1} to eliminate individuals without MON89788. From four BC_3F_1 families of each population, individual BC_3F_2 plants were selected based on maturity that was similar to the recurrent parent. F_3 plants from each BC_3F_2 plant were grown at the Seed Science Center to determine their genotype for MON89788 of each plant. The BC_3F_2 plants with progeny that were homozygous for the MON89788 event were selected and planted in a seed increase row during October 2009 in Puerto Rico. The increase rows of each $BC_3F_{2:4}$ line were harvested in bulk. There were approximately 40 $BC_3F_{2:4}$ lines from each population. Equal amounts of seed from each $BC_3F_{2:4}$ line were bulked within each population to make the BC_3 bulk entry that was used in my study for each experiment.

A separate experiment was grown for each backcross population in 2010. The experiments were grown at Ames, Carlisle, Rippey, and Winterset, IA, in a randomized complete-block design with three replications at each environment. The soil type is a Nicollet loam (fine-loamy, mixed, superactive, mesic Aquic Hapludoll) at Ames, a Tama silty clay loam (fine-silty, mixed, superactive, mesic Typic Agriudoll) at Carlisle, a Nicollet loam (fine-loamy, mixed, mesic Aquic Hapludoll) at Rippey, and a Sharpsburg silty clay loam (fine-montmorillonitic, mesic Typic Argiudoll) at Winterset. The lines were planted on 18 May at Ames, 6 May at Carlisle, 18 May at Rippey, and 24 May at Winterset. The lines were planted in two-row plots 3.05 m long spaced 0.68 m apart within a plot and 0.91 m between adjacent plots at Ames, Carlisle, and Rippey. At Winterset, the lines were planted by Bruce Voss of STAR Services Inc. (Huxley, IA) in two-row plots 5.10 m long spaced 0.76 m apart within and between plots. The seeding rate was 30 seed m^{-1} at all locations.

Each plot was evaluated for yield, maturity, plant height, lodging, seed weight, and concentration of protein, oil, palmitate, stearate, oleate, linoleate, and linolenate in the seed. Maturity was recorded as the d after 31 August when 95% of the pods on the main stem had reached their mature color. Lodging was a visual score from 1 (all plants erect) to 5 (all plants prostrate). Plant height was the length in cm from the ground to the terminal node. All plots were harvested with a plot combine (ALMACO, Nevada, IA), and the weight and moisture of the seed were determined. The plots at Winterset were harvested by Bruce Voss. Yields of the plots were adjusted to 130 g kg^{-1} moisture. Protein and oil concentrations were determined with an Infratec 1221 near-infrared whole grain analyzer (Tecator AB, Hooganas, Sweden) and adjusted to 130 g kg^{-1} moisture. A sample of about 200 seeds from each plot was used to determine seed weight by counting and weighing the seeds and dividing the weight by the number of seeds. Seed size data were collect from only one entry of the recurrent parent (seed source: Ames) out of the 16 check entries in each experiment. Fatty ester content of each plot was determined by analyzing a five-seed bulk by gas chromatography (Hammond, 1991). The samples were analyzed by gas chromatography in the same plot order as was used in the field.

All data were analyzed as a randomized complete-block design using the general linear model (GLM) procedure of SAS version 9.2 (SAS Institute, 2008). Environments and replications were considered random, and the GS lines and GT lines were considered fixed. The sums of squares for genotypes were partitioned into variation among GS lines, variation among GT lines, and the orthogonal contrast between the two types. The mean squares for each component were tested by its interaction with the environment by an *F*-test.

RESULTS AND DISCUSSION

The mean seed yields of the GT lines averaged across environments were not significantly different from the GS lines in the three populations (Table 1). The only environment at which there was a significant difference between the two types was for IA3041BC at Winterset where the mean of the GT lines was 55 kg ha^{-1} (1.6%) greater than for the GS lines (Table 2). There were significant differences in yield among the lines of each type for each of the populations. The 10 highest yielding lines of each population were identified to determine if one of the two types would be more frequently selected for the trait in a cultivar development program (Table 3). When the 30 lines from the three populations were considered together, 14 were GT and 16 were GS. The results indicated that MON89788 did not influence seed yield, which would make it possible to select GT and GS lines from a population that were comparable for the trait.

Although additional GT BC_2-derived lines were included in the study as described earlier, none of those entries yielded better than the 27 GT lines included in my study and did not merit further consideration as future GT cultivars. The mean of the four entries of the recurrent parent of each population was greater than the mean of the BC_3 bulk entries in each population. The mean of the recurrent parent was 110 kg ha^{-1} greater in IA2079BC, 111 kg ha^{-1} greater in IA3028BC and 158 kg ha^{-1} greater in IA3041BC. This indicated that a bulk of the $BC_3F_{2:4}$ lines would not be expected to yield as much as the recurrent parent. In anticipation of this possibility, each of the $BC_3F_{2:4}$ lines in the bulk was yield tested independent of my study as part of a cultivar development program. Only the highest yielding lines in that experiment were used to obtain breeder seed of the cultivars IA2079RR2Y and IA3041RR2Y released by Iowa State

University in November 2010. The GT lines of IA3028 did not yield well and no GT cultivar was released from that backcross program.

The mean maturity of the two types of lines was only significantly different for IA3028BC by 0.4 d (Table 1). This result was expected because GT and GS lines of comparable maturity were selected for the experiments. The mean plant height of the GT lines was significantly greater than the GS lines by 1 cm in IA2079BC and 2 cm in IA3028BC. The mean lodging scores of the two types were not significantly different for any of the populations. The mean seed weight of the GT lines was significantly greater than the GS lines by 2 mg sd^{-1} in IA2079BC and 5 mg sd^{-1} in IA3041BC.

For the seed composition traits, the difference in the mean protein concentrations of the two types was significant by 2 g kg^{-1} in IA3028BC, but was not significant for the other two populations. The mean oil concentration of the two types was not significantly different in IA3041BC, but the difference of 1 g kg^{-1} was significant in the other two populations. The mean palmitate, oleate, and linoleate concentrations were not significantly different between the two types in any of the populations. The mean stearate concentration of the two types was significantly different by 1 g kg^{-1} in IA3041BC. There was a statistically significant difference between the means of the two types for linolenate concentration in IA3041BC, even though the means were the same when rounded to the nearest whole number (Table 1). The mean linolenate concentrations that led to the significant difference were 13.0 g kg^{-1} for the GS type and 13.2 g kg^{-1} for the GT type.

ACKNOWLEDGEMENTS

The authors would like to thank Grace A. Welke and Susan L. Johnson for their assistance in developing the lines used in the study; Kevin O. Scholbrock and Bruce Voss for assistance with collection of field data; and Daniel N. Duvick for the fatty ester analyses.

Table 1. Mean and range for agronomic and seed traits of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines from three populations grown in four Iowa environments in 2010.

		IA2079BC		IA3028BC		IA3041BC	
Trait	Type†	Mean	Range	Mean	Range	Mean	Range
Yield	GS	3691	3408-3893**	3599	3014-3904**	3594	3347-3813**
(kg ha^{-1})	GT	3721ns‡	3438-4058**	3600ns	3278-3853**	3623ns	3275-3954**
Maturity	GS	16.2	14.3-18.2**	19.1	14.0-23.7**	29.7	26.6-30.5**
(d§)	GT	16.3ns	14.7-17.7**	19.5*	14.3-23.1**	29.9ns	27.0-30.4**
Height	GS	87	81-93**	94	85-101**	96	89-104**
(cm)	GT	88*	82-95**	96*	89-104**	98ns	93-107**
Lodging	GS	1.5	1.3-1.9**	2.5	1.8-3.4**	2.5	1.9-3.7**
(score¶)	GT	1.6ns	1.2-1.9**	2.6ns	2.0-3.0**	2.5ns	1.6-3.6**
Seed Wt.	GS	134	121-145**	133	118-155**	137	125-148**
mg sd^{-1}	GT	136*	125-146**	135ns	119-149**	142**	120-153**
Protein	GS	367	358-373**	362	352-376**	350	343-358**
(g kg^{-1}#)	GT	366ns	357-375**	360**	350-370**	350ns	344-358**
Oil	GS	180	176-185**	177	172-183**	173	168-179**
(g kg^{-1}#)	GT	181*	175-190**	178**	173-183**	173ns	168-179**
Palmitate	GS	108	106-112**	105	99-111**	109	105-113**
(g kg^{-1})	GT	108ns	106-111**	104ns	98-111**	109ns	104-114**
Stearate	GS	44	40-46**	45	41-49**	41	35-44**
(g kg^{-1})	GT	44ns	41-46**	45ns	41-48**	40**	36-45**
Oleate	GS	255	227-278**	235	201-270**	246	230-268**
(g kg^{-1})	GT	254ns	233-273**	234ns	214-270**	248ns	219-261**
Linoleate	GS	582	559-610**	602	572-638**	590	569-615**
(g kg^{-1})	GT	582ns	563-602**	603ns	565-627**	590ns	572-614**
Linolenate	GS	12	11-12**	13	13-14**	13	13-14*
(g kg^{-1})	GT	12ns	11-12**	13ns	12-14**	13*	12-14**

* Significant difference at the 0.05 probability level between the means of the two types or among lines within a type.

** Significant difference at the 0.01 probability level between the means of the two types or among lines within a type.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns, difference between the means of the two types or among lines within a type were not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

\# Protein and oil concentrations on a moisture basis of 130 g kg^{-1}.

Table 2. Mean yield of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of three populations at each of four Iowa environments in 2010.

		Environment			
		Ames	Carlisle	Rippey	Winterset
Population	Type†	Mean	Mean	Mean	Mean
		kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
IA2079BC	GS	3573	4489	3110	3592
	GT	3667ns‡	4440ns	3185ns	3593ns
IA3028BC	GS	3612	4012	3341	3432
	GT	3684ns	3985ns	3303ns	3429ns
IA3041BC	GS	3741	4129	3212	3295
	GT	3768ns	4214ns	3163ns	3350*

*Significant difference at the 0.05 probability level between the means of the two types.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns, difference between the means of the two types or among lines within a type were not significant at the 0.05 probability level.

Table 3. Frequency of glyphosate-susceptible and glyphosate-tolerant soybean lines among the 10 highest yielding lines in each of the three populations evaluated during 2010.

Population								
IA2079BC			IA3028 BC			IA3041BC		
Rank	Type†	Yield	Rank	Type	Yield	Rank	Type	Yield
		kg ha^{-1}			kg ha^{-1}			kg ha^{-1}
1	GT	4058	1	GS	3904	1	GT	3954
2	GT	3910	2	GS	3858	2	GT	3880
3	GT	3907	3	GT	3853	3	GS	3813
4	GS	3893	4	GT	3847	4	GT	3804
5	GS	3870	5	GS	3838	5	GS	3802
6	GT	3830	6	GS	3830	6	GT	3794
7	GS	3825	7	GT	3801	7	GS	3764
8	GS	3807	8	GS	3796	8	GS	3754
9	GS	3803	9	GS	3795	9	GT	3740
10	GT	3791	10	GT	3795	10	GS	3734
LSD‡		297			265			276

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ = Least significant difference at the 0.05 probability level.

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CHAPTER 3

Molecular characterization of the mutant *fap3*(A22) allele for reduced palmitate concentration in soybean

From a paper submitted to *Crop Science*

ABSTRACT

Reduction of the palmitate concentration in soybean oil is desirable for reducing the amount of saturated fat in the human diet. Chemical mutagenesis was used to develop the line A22, with the mutant allele designated *fap3*(A22) that reduces palmitate concentration in the seed oil. The objective of our study was to determine the molecular basis of the *fap3*(A22) mutation and develop a corresponding molecular marker to assist in future efforts for developing soybean cultivars with low saturated fat. DNA sequence analysis of *GmFATB1a*, the major 16:0-ACP thioesterase gene of soybean, revealed a single nucleotide polymorphism (SNP) resulting in a nonconservative amino acid substitution that is likely to be detrimental to enzyme function. An association analysis was conducted using F_2-derived lines from a cross between the cultivar Archer (*Fap3Fap3*) and A22 (*fap3fap3*) that had been analyzed for their palmitate concentration by gas chromatography. Molecular genotyping of these lines established a perfect correlation between lines phenotypically classified as homozygous for the *Fap3* allele or homozygous for the *fap3*(A22) allele based on their palmitate concentration. The polymorphism in the *GmFATB1a* gene was used to develop a functional, co-dominant marker that could be used to distinguish the *Fap3* and *fap3*(A22) alleles in segregating populations. This marker will be useful for breeders who are developing low-saturate cultivars with the *fap3*(A22) allele.

MATERIALS AND METHODS

Plant Materials

The soybean cultivar Archer that is homozygous for the wild-type allele *Fap3* and the mutant line A22 that is homozygous for the mutant allele *fap3*(A22) were crossed at the Agricultural and Agronomy Research Center near Ames, IA. The F_1 seeds were planted at the Iowa State University-University of Puerto Rico soybean breeding nursery at Isabela, PR. Individual F_1 plants were harvested and five individual seeds from each plant were evaluated by gas chromatography as described by Hammond (1991) to confirm hybrid plants by segregation for palmitate concentration. There were 220 F_2 seeds and seeds of the two parents planted at Isabela. Individual F_2 and parent plants were harvested.

The two parents and the F_3 progeny of 102 random F_2 plants were planted in a randomized complete-block design with one replication at the Agronomy Farm and one replication at the Burkey Farm of Iowa State University near Ames. The soil type at both locations is a Nicollet loam (fine-loamy, mixed, superactive, mesic Aquic Hapludoll). For each plot, 20 seeds were planted in rows 0.76 m long with a spacing of 1.02 m between rows and an alley 1.07 m wide between the ends of plots. Single pods harvested from the individual plants in each plot were threshed in bulk.

Twenty individual F_4 seeds from each F_2-derived line and 80 individual seeds of each parent were evaluated for palmitate concentration by gas chromatography. The range in palmitate concentration among individual seeds of A22 was 56 to 84 g kg^{-1} and for Archer was 90 to 111 g kg^{-1}. The 20 lines for which all of the 20 seeds had < 84 g kg^{-1} palmitate were considered to be homozygous for the *fap3*(A22) allele and the 21 lines for which all seeds had $>$ 90 g kg^{-1} palmitate were considered to be homozygous for the *Fap3* allele. Lines that had one or more seeds < 84 g kg^{-1} and > 90 g kg^{-1} were assumed to be from F_2 plants with the genotype *Fap3fap3*(A22) and were not used for molecular analysis.

Amplification and Sequence Analysis of the *GmFATB1a* cDNA from A22

To characterize the *GmFATB1a* cDNA from A22, total cellular RNA was isolated from 1 g of young leaf tissue about 14 d after germination using the TRIzol reagent, according to the manufacturer's protocol (Invitrogen, Carlsbad, CA). Poly (A)+ RNA was recovered from 5 μg RNA using the Messagemaker system (Invitrogen, Carlsbad, CA). First-strand cDNA was synthesized from poly (A)+ RNA using an oligo-dT primer and SuperScript II reverse transcriptase (Invitrogen, Carlsbad, CA). A full-length-cDNA was amplified from 20 ng of first-strand A22 cDNA template using the *GmFATB1a*-specific PCR primers described by Cardinal et al. (2007). The amplification product was cloned into the TA vector pCR2.1 (Invitrogen, Carlsbad, CA) and sequenced at the North Carolina State University Genome Sciences Laboratory using an Applied Biosystems 3730 (Applied Biosystems, Carlsbad, CA) capillary sequencer.

Molecular genotyping of F_2-derived lines from Archer X A22 cross

Single leaf disks 1 cm in diameter were harvested from individuals plants of Archer, A22, and individual F_4 plants of the 20 F_2-derived lines phenotypically classified as homozygous for the *fap3*(A22) allele and 21 F_2-derived lines phenotypically classified as *Fap3Fap3*. In all cases, tissue was harvested about 14 d after germination. Leaf disks were ground with liquid nitrogen in 1.5 mL microfuge tubes using plastic pestles. Genomic DNA was isolated from the ground material by adding 325 µL extraction buffer (200 mM Tris HCl pH 7.5, 250 mM NaCl, 25 mM

EDTA, 0.5% SDS) and vortexing for 20 sec. After a 10 min incubation at 65°C, 60 µL of protein precipitation solution (Qiagen, Germantown, MD) was added, and the samples were vortexed briefly before being placed on ice for 5 min. The samples were centrifuged at 16,000 X *g* for 4.5 min and the supernatants transferred to fresh tubes. DNA precipitation was mediated by the addition of 250 µL isopropanol, followed by a 10 min incubation at room temperature and centrifugation at 16,000 X *g* for 7.5 min. After being washed with 70 % ethanol, the pellets were dried and resuspended in 50 µL TE buffer.

PCR assays were conducted in 96-well plates using a MyCyler Thermal Cycler System (BioRad, Hercules, CA). Individual reactions contained 1 µL genomic DNA (typically about 20 ng), 1.5 µL of 10 X *Taq* buffer (New England Biolabs, Ipswich, MA), 6 pmoles of each primer, 200 µM dNTPs (Roche Applied Science, Indianapolis, IN) and 1.5 U of *Taq* DNA polymerase (New England Biolabs, Ipswich, MA) in a total volume of 15 µL. The PCR primers used were the same as those described by Cardinal et al. (2007) to amplify a 312 bp *GmFATB1a*-specific molecular marker designated FATB1a-312. The thermal cycling profile consisted of denaturation at 94°C for 5 min, followed by 30 cycles of 94°C for 30 sec, 52°C for 30 sec, and 72°C for 45 sec, with a final extension at 72°C for 7 min. Excess dNTPs and primers were removed by adding 1 U of Shrimp Alkaline Phosphatase (Promega, Madison, WI) and 2 U Exonuclease I (New England Biolabs, Ipswich, MA) to 7 µL of the PCR product in a total volume of 10 µL. The tubes were incubated at 37°C for 45 min, followed by heat inactivation of the enzymes at 80°C for 15 min. Samples were stored at -20°C until used for sequence analysis.

The PCR products were directly sequenced using either the forward or reverse PCR primers as the sequencing primer in a cycle sequencing labeling reaction using BigDye Terminator version 3.1 (Applied Biosystems, Carlsbad, CA). Each sequencing reaction contained

5 µL PCR DNA, 0.7 µL BigDye, 1.6 µL of 5X buffer and 3.2 pmoles of primer in final volume of 10 µL. Cycling conditions were 95^{o}C for 30 sec, followed by 25 cycles of 96^{o}C for 10 sec, 50^{o}C for 5 sec, and 60^{o}C for 4 min. Removal of the dye terminator was accomplished using Performa DTR Ultra 96-well plates following the manufacturer's protocol (EdgeBio, Gaithersburg, MD). Samples were loaded on an ABI 3730 DNA analyzer (Applied Biosystems, Carlsbad, CA) for sequence determination at the North Carolina State University Genome Sciences Laboratory.

SimpleProbe Marker Development

Ten soybean plants of A22, 'IA1025', Archer, and 'Williams 82' were grown and fresh leaf tissue was harvested in bulk from 10 day-old seedlings. IA1025 was a low-saturate cultivar homozygous and homogeneous for both the *fap1*(C1726) and *fap3*(A22) alleles that reduce palmitate concentration. The fresh plant tissue was lyophilized for 24 h by the Iowa State University DNA Facility and genomic DNA was isolated using an AutoGen 740 (Autogen, Holliston, MA) and a Geno/Grinder 2000 (SPEX CertiPrep Inc., Metuchen, NJ).

A SimpleProbe molecular marker for the *fap3(*A22) allele was developed corresponding to the SNP identified in the *GmFATB1a* gene (Roche Applied Sciences, Indianapolis, IN). The SimpleProbe for the *fap3*(A22) assay, designed by Jason Gillman of the USDA-ARS at the University of Missouri, was 5'-SPC-AAGCCAATCACGGCGCATAC-phosphate-3'. Asymmetric PCR was carried out to maximize single stranded DNA synthesis for probe binding. The assay was performed with an asymmetric mixture of the forward primer (5'-TGACATAGTTCAAGTGGACACT-3') at 0.2 µM and reverse primer (5'-GCAAAATGCAAATGATTACCTG-3') at 0.5 µM final concentration. Reactions were carried out in a total volume of 20 μL containing template, primers, SimpleProbe (0.4 μM final concentration), buffer (40 mM Tricine-KOH (pH 8.0), 16 mM KCl, 3.5 mM $MgCl_2$, 3.75 μg ml^{-1} BSA, 200 μM dNTPs, 5% DMSO and 0.2X Titanium *Taq* polymerase (BD Biosciences, Sparks, MD). Genotyping reactions were performed using a Lightcycler 480 II real time PCR instrument (Roche Applied Sciences, Indianapolis, IN) with the following PCR parameters: 95˚C for 5 min followed by 40 cycles of 95˚C for 30 sec, 60˚C for 30 sec, 72˚C for 30 sec, and a melting curve from 48 to 72˚C. Fluorescence was read every 0.1˚C during the melting curve analysis.

RESULTS AND DISCUSSION

Sequence Analysis of *GmFATB1a* in A22

Cardinal et al. (2007) concluded that a naturally occurring deletion mutation of the *GmFATB1a* gene was the molecular basis of the $fap3_{nc}$ allele that originated from germplasm line N79-2077-12. Given the allelic nature of *fap3*(A22) and $fap3_{nc}$, *GmFATB1a* was considered the prime target of the mutagen that generated the *fap3*(A22) allele. To determine whether any deleterious mutations could be found in the *GmFATB1a* gene from A22, DNA sequence analysis of the full-length cDNA was conducted using mRNA isolated from developing seeds. Comparison of the *GmFATB1a* cDNA sequence from A22 with the sequence previously obtained from the normal-palmitate cultivar Century (Cardinal et al., 2007) revealed only one polymorphism that would alter the predicted amino acid sequence of the enzyme. The G to T substitution at nucleotide position 693 (with respect to the initiation codon) of the cDNA changed a Trp residue at amino acid position 231 to a Leu. Homology searches using the BLASTP algorithm (Altschul et al., 1990) of the nonredundant protein database of GenBank with the predicted amino acid sequence of *GmFATB1a* from A22 revealed that every plant protein annotated as a 16:0-ACP TE possessed a Trp residue at the position comparable to position 231 of the soybean sequence (data not shown). This high degree of sequence conservation strongly suggested that a Trp amino acid at this position was important in maintaining the functionality of the enzyme.

The SNP responsible for the Trp231Leu mutation lies within a genomic fragment of *GmFATB1a* DNA that was previously used as a diagnostic molecular marker (designated FATB1a-312) for assaying the presence or absence of *GmFATB1a* in a soybean population segregating for the $fap3_{nc}$ allele (Cardinal et al., 2007). As shown in Figure 1, the G to T mutation found in A22 is located at position 63 within the 312 bp PCR amplification product of FATB1a-312. Using the same PCR primers described by Cardinal et al. (2007), a 312 bp PCR product was amplified and sequenced from the parental lines Archer and A22, and from a single F_4 plant from each of the 20 F_2-derived lines that were classified as *fap3*(A22)*fap3*(A22) and each of the 21 lines classified as *Fap3Fap3*. Figure 1 shows the DNA sequence of this 312 bp region from Archer and A22, as well as Williams 82 and Century that were used as additional reference genomes. In addition to the G63T SNP responsible for the Trp231Leu mutation, a cultivar-specific SNP that does not alter the protein sequence was observed at position 55. In Archer, a C nucleotide resides at this location, whereas in Century, Williams 82 and A22, a T nucleotide is found (Fig. 1).

DNA sequence analysis showed that the 20 F_2-derived lines classified phenotypically as homozygous for the *fap3*(A22) allele were homozygous for the T at position 63 within the FATB1a-312 fragment, as well as a C at position 55 that originated from A22. All of the 21 F_2-derived lines classified phenotypically as homozygous for the *Fap*3 allele were homozygous for a G at position 63 and a T at position 55 inherited from Archer. This perfect correlation provided strong support for the hypothesis that the SNP giving rise to the Trp231Leu amino acid substitution in the *GmFATB1a* gene originating from A22 is the causative basis for the *fap3*(A22) allele.

Molecular Marker Assay

The direct DNA sequence analysis of the 312 bp PCR products of the FATB1a-312 marker were effective in establishing a correlation between the G63T SNP and the *fap3*(A22) allele. This sequence information for the G63T SNP and its surrounding genomic region was used to develop a SimpleProbe molecular marker assay to differentiate the *Fap3* and *fap3*(A22) alleles. SimpleProbe assays are based upon the disassociation kinetics of a fluorescent oligonucleotide probe that binds perfectly to a wild type sequence, but has a single mismatch base pair when bound to a mutant sequence, or vice versa (Gillman et al., 2009). The oligonucleotide probe changes from a fluorescent state when bound to the corresponding strand to a non-fluorescent state when unbound. The difference in the fluorescence as the probe disassociates from the mutant or wild type sequence with increasing temperature allows for determination of what nucleotide is present at the polymorphic site.

The specific *GmFATB1a* sequence that was the target of the designed SimpleProbe is shown in Figure 1. In addition to being complementary to the G63T SNP associated with the *fap3*(A22) locus, the SimpleProbe also spans the nearby C55T SNP observed in Archer. Therefore, the SimpleProbe would be expected to hybridize perfectly to DNA isolated from cultivars such as Williams 82 and Century, have a single mismatch at position 55 of the FATB1a-312 fragment from Archer, and a single mismatch at position 63 using A22 DNA.

To establish the effectiveness of the SimpleProbe assay, genomic DNA preparations from A22, IA1025, Archer, and Williams 82 were evaluated. PCR amplification products from A22 and IA1025 genomic DNA samples had a SimpleProbe melting temperature of 58˚C, while Archer had a melting temperature of 62˚C (Fig. 2). A heterozygous individual displayed melting curves at both 58˚C and 62˚C. Figure 2 shows the expected melting curves for the three possible genotypes when the C55T polymorphism is present in addition to the G63T SNP. Due to the perfect complimentarily between the SimpleProbe and the Williams 82 sequence, assays conducted using this source of DNA had the highest melting temperature of 66.5˚C. Figure 3 shows the observed melting curves for the three possible genotypes when comparing individuals with only the G63T SNP present. The observed temperature curves were consistent with what was expected based on the dissociation kinetics of the probe that was designed over the region. The intermediate temperature curve of Archer suggested that the mismatched base pair is nearer the 3’ end of the probe, which allowed it to bind to the sequence at a higher temperature than the *fap3*(A22) mutation.

To evaluate the effectiveness of the SimpleProbe assay, leaf tissue from 80 plants were sampled from a F_2 population that was segregating for the *fap3*(A22) allele. The parents of the population were ‘IA1024’ [*fap3*(A22)*fap3*(A22)] and ‘IA2053’ (*Fap3Fap3*). The parents and population were developed by Iowa State University and grown at the Agricultural and Agronomy Research Center near Ames. Four samples of A22, Archer, and the two parents of the population were analyzed with the 80 F_2 samples in a 96-well format. All samples of A22 and IA1024 displayed the expected melting temperature of 58˚C, while all samples of Archer melted at the expected temperature of 62˚C. The four samples of IA2053 had a melting temperature of 66.5˚C, which suggested that this cultivar did not contain the benign C55T polymorphism that was observed in the *GmFATB1a* gene of Archer. Of the 80 F_2 samples, 18 had melting profiles corresponding to the *fap3*(A22)*fap3*(A22) genotype (T at position 63), 41 had temperatures corresponding to *Fap3fap3*(A22) genotype (heterozygous at position 63), and 21 had temperatures corresponding to *Fap3Fap3* genotype (G at position 63). These results satisfactorily fit the expected 1:2:1 ratio based on a Chi-squared test (P=0.87) (Cochran, 1952).

In summary, the results of our study indicated that the G63T SNP associated with the FATB1a-312 molecular marker that converts the Trp residue normally found at position 231 of the soybean 16:0-ACP TE enzyme to a Leu residue was the causative mutation of the *fap3*(A22) allele. The SimpleProbe marker developed in this study should be useful as a tool for breeders who use *fap3*(A22) to develop low-saturate cultivars.

ACKNOWLEDGEMENTS

The authors would like to thank Ralph E. Dewey and his research group from N.C. State for doing sequence analysis; Grace A. Welke and Susan L. Johnson for their assistance in line development; Silvia Cianzio for growing and harvesting the F_1 and F_2 plants; Daniel N. Duvick for assistance with analysis of fatty ester contents of oil samples; and Elinor Fehr for assistance with preparation of the figures.

Fig 1. Alignment of genomic sequences of a 312 bp fragment of *GmFATB1a* genes from Williams 82, Archer, A22 obtained in this study and that of Century from GenBank accession number DQ861997. Shaded text corresponds to annealing sites of the PCR primers while underlined sequence corresponds to the SimpleProbe binding region. The first arrow indicates a benign cultivar-specific SNP observed in the Archer gene at position 55. The second arrow indicates the G63T mutation that is considered to be the causative SNP for the *fap3*(A22) allele.

```
W82       (1)     TGACATAGTTCAAGTGGACACTTGGGTTTCTGGATCAGGGAAGAATGGTATGCGCCGTGA
Century   (1)     TGACATAGTTCAAGTGGACACTTGGGTTTCTGGATCAGGGAAGAATGGTATGCGCCGTGA
Archer    (1)     TGACATAGTTCAAGTGGACACTTGGGTTTCTGGATCAGGGAAGAATGGTATGCGTCGTGA
A22       (1)     TGACATAGTTCAAGTGGACACTTGGGTTTCTGGATCAGGGAAGAATGGTATGCGCCGTGA

W82       (61)    TTGGCTTTTACGTGACTGCAAAACTGGTGAAATCTTGACAAGAGCTTCCAGGTAGAAATC
Century   (61)    TTGGCTTTTACGTGACTGCAAAACTGGTGAAATCTTGACAAGAGCTTCCAGGTAGAAATC
Archer    (61)    TTGGCTTTTACGTGACTGCAAAACTGGTGAAATCTTGACAAGAGCTTCCAGGTAGAAATC
A22       (61)    TTTGCTTTTACGTGACTGCAAAACTGGTGAAATCTTGACAAGAGCTTCCAGGTAGAAATC

W82       (121)   ATTCTCTGGAATTTTCCTTCCCCTTTCCTTCTGCTTCAAGCAAATTTTAAGATGTGTATC
Century   (121)   ATTCTCTGGAATTTTCCTTCCCCTTTCCTTCTGCTTCAAGCAAATTTTAAGATGTGTATC
Archer    (121)   ATTCTCTGGAATTTTCCTTCCCCTTTCCTTCTGCTTCAAGCAAATTTTAAGATGTGTATC
A22       (121)   ATTCTCTGGAATTTTCCTTCCCCTTTCCTTCTGCTTCAAGCAAATTTTAAGATGTGTATC

W82       (181)   TTAATGTACTTGATGGTGATTGGGCACAATTTTGAATCTTCCATACATTTTAAAAGTTAT
Century   (181)   TTAATGTACTTGATGGTGATTGGGCACAATTTTGAATCTTCCATACATTTTAAAAGTTAT
Archer    (181)   TTAATGTACTTGATGGTGATTGGGCACAATTTTGAATCTTCCATACATTTTAAAAGTTAT
A22       (181)   TTAATGTACTTGATGGTGATTGGGCACAATTTTGAATCTTCCATACATTTTAAAAGTTAT

W82       (241)   GGAACCCTTTCTTTTCCTTCTTAAGATGCAAATTTGTCATGACTGAAGTTTCAGGTAATC
Century   (241)   GGAACCCTTTCTTTTCCTTCTTAAGATGCAAATTTGTCATGACTGAAGTTTCAGGTAATC
Archer    (241)   GGAACCCTTTCTTTTCCTTCTTAAGATGCAAATTTGTCATGACTGAAGTTTCAGGTAATC
A22       (241)   GGAACCCTTTCTTTTCCTTCTTAAGATGCAAATTTGTCATGACTGAAGTTTCAGGTAATC

W82       (301)   ATTTGCATTTTGC
Century   (301)   ATTTGCATTTTGC
Archer    (301)   ATTTGCATTTTGC
A22       (301)   ATTTGCATTTTGC
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Fig 2. Melting curve analysis of samples genotyped using the SimpleProbe assay. A single peak at 58°C corresponds to a sample homozygous for the *fap3*(A22) allele that contains the G63T mutation. A single peak at 62.5°C corresponds to a sample homozygous for the *Fap3* allele that contains the C55T mutation found in Archer. Samples yielding both curves represent heterozygous genotypes.

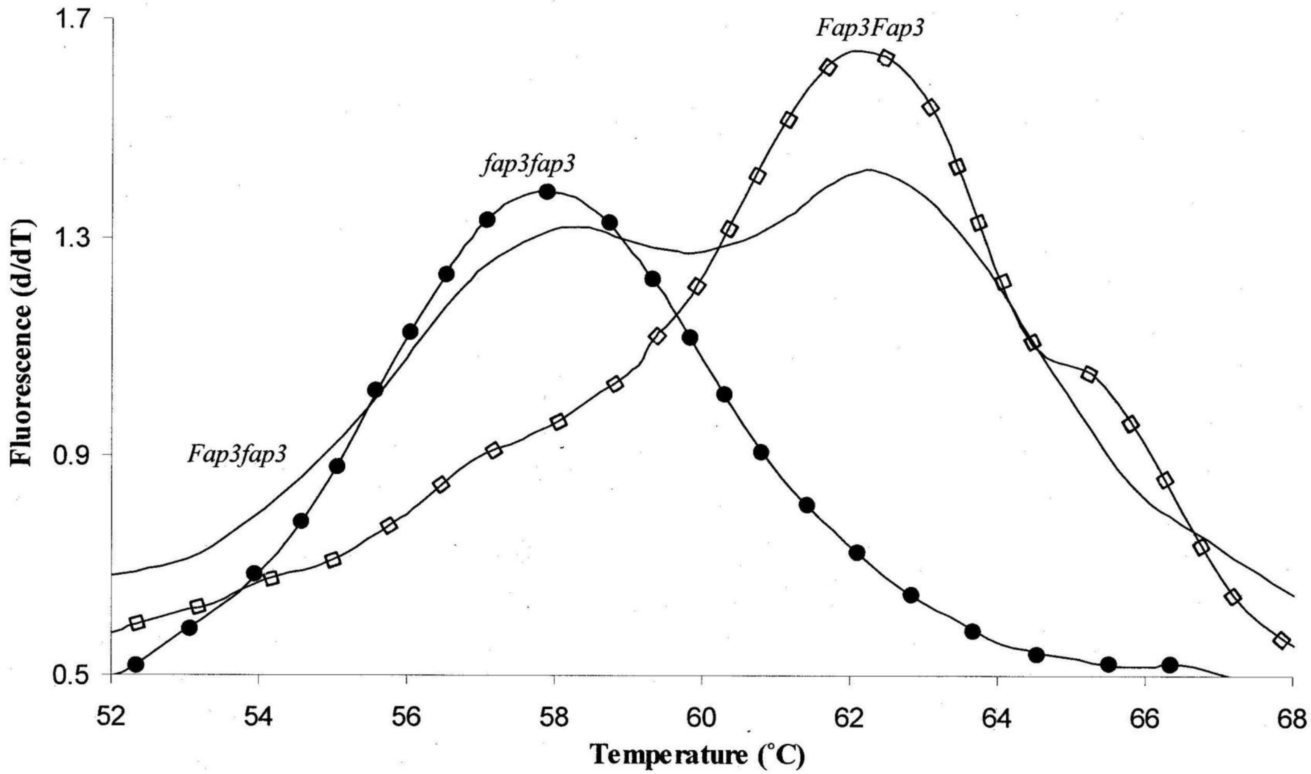
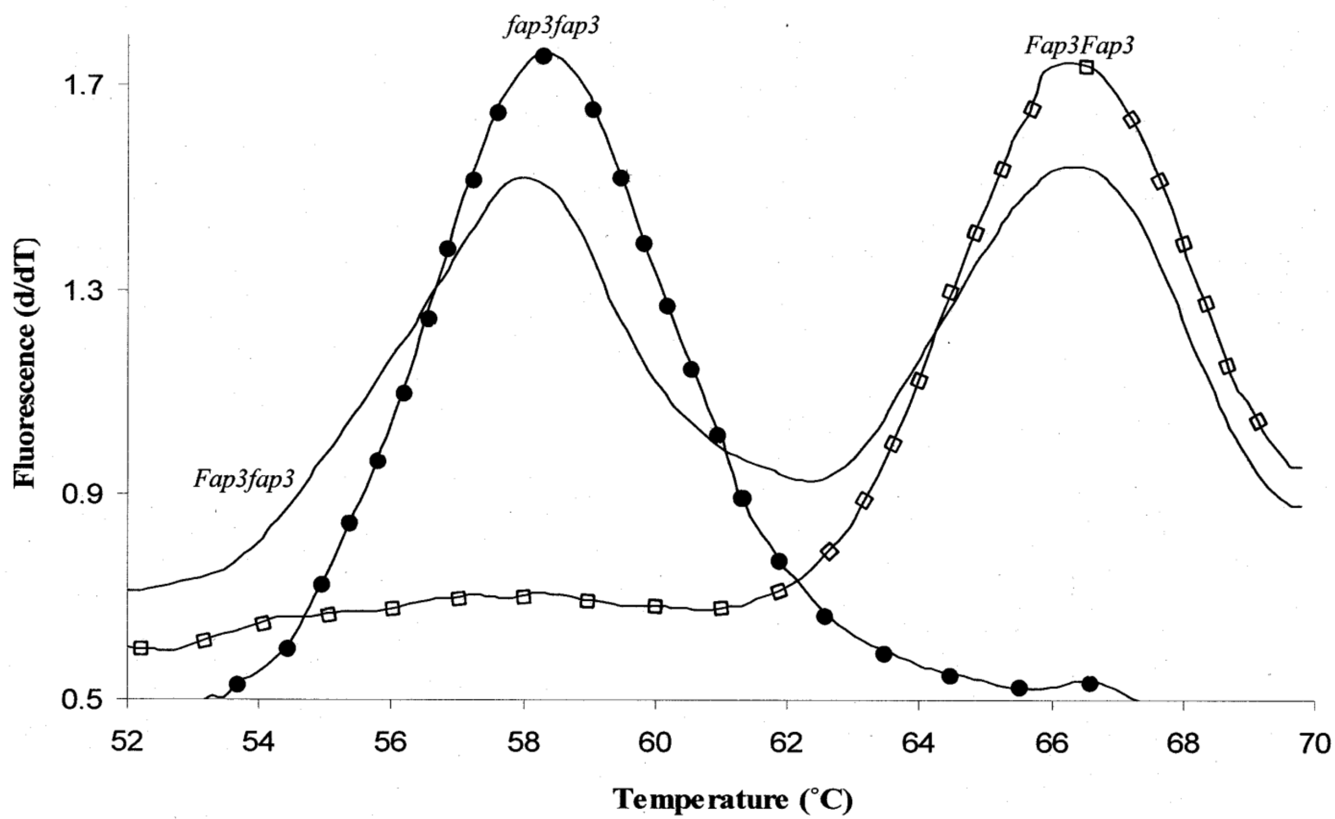


Fig 3. Melting curve analysis of samples genotyped using the SimpleProbe assay. A single peak at 58°C corresponds to a sample homozygous for the *fap3*(A22) allele that contains the G63T mutation. A single peak at 66.5°C corresponds to a sample homozygous for the *Fap3* allele that does not have the C55T mutation found in Archer. Samples yielding both curves represent heterozygous genotype.



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CHAPTER 4

GENERAL CONCLUSIONS

Although there were significant differences between the means of the two types for some of the traits in some of the populations, there were significant differences among the lines within the GT and GS types for all of the traits and the distributions among lines of the two types overlapped (Table 1). As a result, it would be possible to select GT cultivars that are similar to GS cultivars for all of the traits evaluated in our study from populations developed by crossing a GS parent to a GT parent.

The lack of a negative influence of MON89788 on seed yield differed from that reported by Elmore et al. (2001) for lines containing the 40-3-2 event for glyphosate tolerance. They observed a 5% lower mean seed yield for GT lines than GS lines and indicated that the difference was related to the gene or its insertion process. The difference between our results obtained with MON89788 and those of Elmore et al. (2001) for 40-3-2 may be due to one or more of the five factors that differed between the development of the two events as described by Meyer et al. (2006) and Padgette et al. (1995).

The G63T SNP associated with the FATB1a-312 molecular marker that converts the Trp residue normally found at position 231 of the soybean 16:0-ACP TE enzyme to a Leu residue was the causative mutation of the *fap3*(A22) allele. The SimpleProbe marker developed in this study should be useful as a tool for breeders who use *fap3*(A22) to develop low-saturate cultivars.

APPENDIX A

ANALYSES OF VARIANCE AND ENTRY MEANS FOR SEED TRAITS ACROSS ENVIRONMENTS FOR GLYPHOSATE-TOLERANT AND GLYPHOSATE-SUSCEPTIBLE LINE

Table A1. Analyses of variance for seed yield of three populations across four Iowa environments in 2010.

	Mean Squares					
	IA2079 BC		IA3028 BC		IA3041 BC	
Sources of Variation†	df	Yield (kg ha^{-1})	df	Yield (kg ha^{-1})	df	Yield (kg ha^{-1})
Environments (Env)	3	49020221.9**	3	14422326.6**	3	32234344.8**
Replications/Env	8	833417.0**	8	670736.4**	8	821021.1**
Genotypes	53	169631.3ns†	53	408512.8**	53	249746.3**
GS	26	156824.3ns	26	551789.4**	26	212343.9*
GT	26	183291.2ns	26	280940.4**	26	291313.9**
GS vs. GT	1	147454.7ns	1	205.6ns	1	141452.9ns
Genotypes x Env	159	135456.8**	159	107843.1**	159	117248.4**
GS x Env	78	145948.1**	78	141271.4**	78	108977.2*
GT x Env	78	123311.8*	78	74701.2ns	78	124969.7**
GS vs. GT x Env	3	178454.2ns	3	100399.4ns	3	131544.8ns
Error	401	91660.0	410	74696.2	411	78869.9
CV (%)		8.1		7.6		7.8

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

Table A2. Analyses of variance for 11 agronomic and seed traits measured in the IA2079BC experiment across four Iowa environments in 2010.

		Mean Squares					
Sources of Variation†	df	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})	Seed weight (mg $seed^{-1}$)
Environments (Env)	3	328.7**	10028.2**	24.7**	5346.0**	3089.5**	21186.7**
Replications/Env	8	9.5**	399.5**	0.2ns‡	429.3**	59.7**	663.2**
Genotypes	53	11.4**	120.7**	0.3**	308.0**	121.2**	498.6**
GS	26	15.9**	92.3**	0.3**	242.6**	65.7**	560.3**
GT	26	7.3**	142.2**	0.4**	381.4**	174.0**	442.3**
GS vs. GT	1	0.5ns	298.8*	0.4ns	99.6ns	190.1*	358.5*
Genotypes x Env	159	1.7ns	36.5ns	0.1ns	15.5ns	7.0**	47.1ns
GS x Env	78	1.7ns	37.3ns	0.1ns	15.1ns	7.0*	48.8ns
GT x Env	78	1.6ns	36.1ns	0.1ns	15.0**	6.7*	46.5ns
GS vs. GT x Env	3	0.5ns	22.8ns	0.4*	38.2*	14.9*	17.3ns
Error	401	1.6	35.2	0.1	12.8	4.9	38.1
CV (%)		7.7	6.8	6.8	0.9	1.2	4.6

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table A2. Continued

		Mean Squares				
Sources of Variation	df	Palmitate ($g\ kg^{-1}$)	Stearate ($g\ kg^{-1}$)	Oleate ($g\ kg^{-1}$)	Linoleate ($g\ kg^{-1}$)	Linolenate ($g\ kg^{-1}$)
Environments (Env)	3	364.0**	559.8**	4274.4*	5730.1*	13.0*
Replications/Env	8	18.2**	7.4ns	968.8**	1003.3**	2.1**
Genotypes	53	23.4**	28.9**	1118.1**	1140.7**	1.3**
GS	26	32.4**	25.7**	1384.0**	1429.3**	1.4**
GT	26	14.7**	33.2**	894.7**	892.7**	1.2**
GS vs. GT	1	14.2ns	2.9ns	12.5ns	83.8ns	0.9ns
Genotypes x Env	159	4.32ns	5.3*	204.8*	199.8*	0.5ns
GS x Env	78	6.5**	5.5ns	188.8ns	183.4ns	0.5ns
GT x Env	78	2.2ns	4.9ns	227.1*	221.4*	0.5ns
GS vs. GT x Env	3	3.6ns	8.4ns	40.8ns	62.6ns	0.6ns
Error	401	3.8	4.2	156.6	161.3	0.5
CV (%)		1.8	4.7	4.9	2.2	3.9

Table A3. Analyses of variance for 11 agronomic and seed traits measured in the IA3028BC experiment across four Iowa environments in 2010.

		Mean Squares					
Sources of Variation†	df	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})	Seed weight (mg $seed^{-1}$)
Environments (Env)	3	337.2**	1076.0ns‡	62.5**	4715.2**	2392.9**	4919.0**
Replications/Env	8	13.7**	352.4**	0.9**	88.0**	29.3**	639.5**
Genotypes	53	58.7**	226.4**	1.6**	423.0**	101.9**	1048.0**
GS	26	67.6**	210.6**	2.4**	408.1**	90.4**	1146.7**
GT	26	51.3**	200.7**	0.7**	437.9**	108.4**	964.2**
GS vs. GT	1	19.7*	1306.2*	1.3ns	420.5**	232.3**	659.0ns
Genotypes x Env	159	2.5**	48.8*	0.2**	17.4**	8.9**	49.2*
GS x Env	78	1.8ns	53.4*	0.2*	14.3*	8.5**	32.5ns
GT x Env	78	3.2**	42.1ns	0.2**	20.8**	9.5**	59.4**
GS vs. GT x Env	3	1.2ns	103.3*	0.4ns	10.1ns	4.8ns	218.4**
Error	410	1.6	37.5	0.2	10.8	4.3	37.3
CV (%)		6.5	6.4	15.9	0.9	1.2	4.6

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines

‡ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table A3. Continued

Sources of Variation	df	Mean Squares Palmitate ($g\ kg^{-1}$)	Stearate ($g\ kg^{-1}$)	Oleate ($g\ kg^{-1}$)	Linoleate ($g\ kg^{-1}$)	Linolenate ($g\ kg^{-1}$)
Environments (Env)	3	398.4**	645.0**	12130.1**	12066.5**	9.5ns
Replications/Env	8	21.3**	36.6**	834.4**	1027.6**	3.8**
Genotypes	53	141.0**	41.2**	3585.9**	4035.4**	2.5**
GS	26	133.4**	42.6**	4810.7**	5111.0**	2.2**
GT	26	153.8**	40.8**	2493.1**	3099.7**	2.8**
GS vs. GT	1	5.5ns	14.8ns	152.1ns	398.2ns	3.1**
Genotypes x Env	159	5.8ns	9.7ns	261.2*	298.0*	0.5ns
GS x Env	78	6.1ns	9.7ns	266.2ns	290.2ns	0.6**
GT x Env	78	5.4ns	9.8ns	262.7ns	313.7ns	0.3ns
GS vs. GT x Env	3	8.0ns	5.1ns	92.1ns	90.3ns	0.8ns
Error	410	6.0	8.3	204.1	240.2	0.4
CV (%)		2.3	6.4	3.1	2.6	4.8

Table A4. Analyses of variance for 11 agronomic and seed traits measured in the IA3041BC experiment across four Iowa environments in 2010.

		Mean Squares					
Sources of Variation†	df	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})	Seed weight (mg seed^{-1})
Environments (Env)	3	1213.5**	1423.4ns‡	44.9**	9744.3**	1851.4**	3724.0*
Replications/Env	8	8.5**	962.9**	4.2**	115.9**	78.1**	496.7**
Genotypes	53	10.0**	186.1**	2.5**	151.1**	86.2**	598.3**
GS	26	12.3**	176.5**	3.3**	200.6**	58.9**	497.0**
GT	26	7.8**	175.5**	1.9**	106.8**	88.8**	559.8**
GS vs. GT	1	5.7ns	709.4ns	0.0ns	16.7ns	36.1ns	4237.1**
Genotypes x Env	159	1.9**	58.0*	0.2ns	12.5ns	5.0ns	44.5**
GS x Env	78	1.6**	69.5**	0.2ns	16.1ns	5.5*	29.6ns
GT x Env	78	2.1**	45.7ns	0.2ns	9.3ns	4.5ns	59.4**
GS vs. GT x Env	3	2.5ns	79.0ns	0.0ns	3.7ns	6.1ns	46.1ns
Error	411	1.1	44.2	0.2	13.1	4.1	32.4
CV (%)		3.6	6.8	18.4	1.0	1.2	4.1

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table A4. Continued

		Mean Squares				
Sources of Variation	df	Palmitate ($g\ kg^{-1}$)	Stearate ($g\ kg^{-1}$)	Oleate ($g\ kg^{-1}$)	Linoleate ($g\ kg^{-1}$)	Linolenate ($g\ kg^{-1}$)
Environments (Env)	3	899.5**	328.0**	19525.8**	18648.5**	4.1ns
Replications/Env	8	15.7**	9.2ns	2275.0**	2366.6**	2.2**
Genotypes	53	54.5**	78.4**	1133.6**	1142.3**	1.3**
GS	26	42.8**	66.0**	1284.0**	1403.5**	0.9*
GT	26	67.7**	89.5**	1012.7**	924.9**	1.7**
GS vs. GT	1	16.7ns	112.5**	366.0ns	4.0ns	3.6*
Genotypes x Env	159	5.3ns	4.3ns	280.8ns	267.6ns	0.5ns
GS x Env	78	5.8*	4.9ns	277.6ns	262.2ns	0.5ns
GT x Env	78	4.6ns	3.5ns	294.0ns	281.2ns	0.6*
GS vs. GT x Env	3	11.3ns	6.5ns	20.9ns	51.7ns	0.3ns
Error	411	4.3	5.4	250.4	254.9	0.4
CV (%)		1.9	57	6.4	2.7	5.0

Table A5. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA2079BC, the recurrent parent, and check entries grown in four Iowa environments in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		$kg\ ha^{-1}$	days‡	cm	score§	$g\ kg^{-1}$¶	$g\ kg^{-1}$¶	$mg\ sd^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$
458001	GS	3580	16.3	85	1.4	371	176	135	112	44	261	571	12
458002	GS	3695	14.3	87	1.5	371	180	134	106	46	278	559	12
458003	GS	3627	15.6	81	1.4	365	180	121	110	45	250	584	12
458004	GS	3632	14.7	83	1.7	364	177	125	108	45	241	594	13
458005	GS	3610	15.0	89	1.5	365	179	125	107	46	259	575	12
458006	GS	3642	16.3	85	1.6	367	177	125	110	44	251	583	12
458007	GS	3710	14.5	87	1.7	369	179	140	107	43	263	576	11
458008	GS	3540	15.0	89	1.8	367	179	128	107	46	260	577	11
458009	GS	3408	15.8	86	1.7	371	177	131	109	44	265	570	11
458010	GS	3668	14.3	90	1.6	373	180	141	108	40	276	564	12
458011	GS	3723	16.2	90	1.5	373	178	139	110	40	257	582	12
458012	GS	3654	16.5	92	1.6	373	178	140	110	43	259	576	12
458013	GS	3595	17.8	87	1.5	367	178	137	110	45	251	583	12
458014	GS	3746	16.2	83	1.3	363	182	136	110	42	248	588	11
458015	GS	3825	16.9	88	1.9	364	180	139	108	42	253	584	12
458016	GS	3450	14.9	86	1.5	373	181	144	108	43	261	576	12
458017	GS	3807	16.7	87	1.7	366	180	137	108	44	253	581	12
458018	GS	3777	16.6	91	1.4	371	179	142	109	42	263	574	11
458019	GS	3893	17.0	89	1.6	359	184	134	108	46	264	571	11
458020	GS	3803	17.7	89	1.5	358	185	137	106	44	248	591	11
458021	GS	3696	17.7	87	1.8	365	179	127	106	43	242	597	11

Table A5. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
458022	GS	3870	18.1	89	1.5	363	182	141	106	44	245	594	12
458023	GS	3717	16.2	86	1.5	362	184	130	108	44	242	595	11
458024	GS	3763	16.8	88	1.5	365	181	131	107	44	251	587	11
458025	GS	3736	18.2	90	1.7	366	181	145	107	44	255	581	11
458026	GS	3767	16.8	85	1.3	366	181	136	108	44	254	582	12
458027	GS	3692	17.2	82	1.2	359	182	122	108	43	227	609	12
458028	GR	3780	15.9	89	1.7	370	177	137	109	44	252	583	12
458029	GR	3685	15.4	84	1.3	368	176	127	108	43	249	588	12
458030	GR	3683	15.3	87	1.7	365	180	126	107	45	261	575	12
458031	GR	3597	15.3	84	1.5	368	177	128	107	45	259	576	12
458032	GR	3614	16.8	88	1.7	364	181	134	107	43	256	581	12
458033	GR	3438	15.3	84	1.7	375	175	140	106	47	267	569	12
458034	GR	3744	16.0	82	1.7	362	180	125	111	45	245	588	12
458035	GR	3787	15.7	85	1.7	366	177	130	108	45	253	285	12
458036	GR	3767	15.8	91	1.8	369	178	130	106	46	265	571	11
458037	GR	3673	16.4	94	1.7	375	176	146	110	41	265	572	12
458038	GR	3682	16.1	94	1.7	374	181	145	108	41	263	575	12
458039	GR	3647	14.7	91	1.7	373	182	144	108	44	272	564	12
458040	GR	3753	15.6	89	1.5	367	181	136	109	42	262	576	11
458041	GR	3735	17.4	91	1.9	372	179	146	109	41	251	588	11
458042	GR	3742	16.8	93	1.6	369	178	137	108	41	251	586	12
458043	GR	3681	16.6	93	1.8	369	180	136	108	45	255	581	12
458044	GR	3618	16.3	90	1.8	367	180	139	109	42	248	589	12
458045	GR	3540	17.0	91	1.8	370	180	137	109	41	263	574	12

Table A5. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458046	GR	3907	17.4	92	1.8	358	184	133	107	43	248	591	11
458047	GR	3791	17.3	88	1.5	357	188	143	106	44	247	591	11
458048	GR	3721	16.5	90	1.6	359	186	133	107	45	249	588	11
458049	GR	3830	16.8	87	1.5	364	186	139	107	43	256	583	11
458050	GR	3707	16.5	90	1.7	358	186	130	107	45	249	587	11
458051	GR	3595	16.6	85	1.2	359	185	138	108	44	253	584	11
458052	GR	4059	17.7	86	1.2	364	182	133	109	45	233	602	12
458053	GR	3910	16.4	85	1.3	362	183	133	108	43	242	596	11
458054	GR	3787	17.4	87	1.5	358	189	139	108	44	255	583	11
458055	BC2-YT (GT)	3607	16.3	89	1.7	369	176		109	45	263	572	11
458056	BC2-YT (GT)	3551	17.2	93	1.7	371	179		108	43	257	580	12
458057	BC2-YT (GT)	3877	18.6	86	1.5	357	185		107	44	240	598	11
458058	BC2-YT (GT)	3563	16.3	89	1.6	363	185		107	44	258	580	11
458059	BC2-YT (GT)	3728	19.3	93	1.7	359	184		106	44	258	581	12
458060	BC2-YT (GT)	3857	18.3	93	1.5	363	183		106	44	262	576	11
458061	BC2-YT (GT)	3734	16.3	85	1.7	358	185		107	43	250	589	11
458062	IA2079 (GS)	3797	15.6	89	1.5	364	183	132	107	43	251	586	12
458063	IA2079 (GS)	3585	16.3	86	1.6	366	182		108	44	254	583	12
458064	IA2079 (GS)#	3754	15.7	89	1.6	363	183		107	44	255	582	11
458065	IA2079 (GS)#	3655	15.8	88	1.7	365	183		106	43	254	586	11
458066	BC3-bulk (GS)#	3609	18.0	92	1.8	367	178		108	41	239	600	12
458067	BC3-bulk (GS)#	3566	18.6	87	1.6	366	178		109	41	239	600	12
458068	CSR2252N (GT)	3413	14.9	86	1.3	354	191		105	39	225	563	68
458069	CSR2522N (GT)	3590	16.7	87	1.5	354	186		115	42	240	529	74

Table A5. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458070	CSR2682N (GT)	3891	20.4	87	1.3	352	186		103	38	217	564	77
SEM††		106.2	0.4	1.7	0.1	1.1	0.8	2.0	0.6	0.7	4.1	4.0	0.2
LSD 0.05††		296.8	1.0	4.9	0.3	3.2	2.1	5.5	1.7	1.8	11.5	11.4	0.6
LSD 0.01††		391.7	1.4	6.4	0.4	4.2	2.8	7.3	2.2	2.4	15.2	15.0	0.7

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.
‡ Days after 31 August.
§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).
¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.
# Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.
†† Entries 458055 through 458070 were not included in this calculation.

Table A6. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA3028BC, the recurrent parent, and check entries grown in four Iowa environments in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days‡	cm	score§	g kg^{-1}¶	g kg^{-1}¶	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
459001	GS	3725	18.7	100	2.3	356	183	143	102	45	241	598	13
459002	GS	3728	17.1	90	2.0	363	179	132	107	46	244	590	13
459003	GS	3796	19.8	98	2.4	353	181	145	101	47	263	577	13
459004	GS	3698	18.7	93	2.0	357	182	137	102	47	246	592	13
459005	GS	3795	18.6	92	2.4	355	177	138	106	47	262	572	13
459006	GS	3523	17.1	97	2.3	361	180	132	109	45	222	610	13
459007	GS	3830	18.0	94	2.2	357	179	143	107	49	257	574	13
459008	GS	3904	17.8	89	1.8	360	178	141	101	45	256	581	14
459009	GS	3858	19.3	95	1.9	358	179	137	100	46	267	575	13
459010	GS	3745	18.6	95	2.2	358	176	119	101	45	222	618	13
459011	GS	3650	19.0	99	2.5	363	175	124	104	44	220	618	14
459012	GS	3669	20.9	91	2.5	364	172	124	106	44	215	622	14
459013	GS	3726	20.0	94	2.7	352	182	124	101	44	222	621	13
459014	GS	3450	17.0	90	2.0	364	178	126	106	45	252	583	14
459015	GS	3660	18.4	92	2.3	360	175	120	102	42	210	634	13
459016	GS	3683	18.1	87	2.3	361	175	118	107	41	201	638	14
459017	GS	3421	14.2	85	2.0	367	174	121	105	42	208	632	14
459018	GS	3629	19.8	92	1.9	354	180	124	103	42	219	622	13
459019	GS	3838	23.3	91	2.4	365	175	134	108	45	215	618	14
459020	GS	3421	20.4	101	2.9	370	175	127	103	46	236	601	14
459021	GS	3523	23.7	100	2.8	365	175	147	103	47	248	587	14

Table A6. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
459022	GS	3014	14.0	90	3.4	376	176	140	99	45	270	572	14
459023	GS	3572	22.5	101	3.1	362	177	133	108	47	235	596	14
459024	GS	3411	22.2	94	2.7	373	173	155	108	46	249	583	14
459025	GS	3384	22.3	92	3.0	365	177	143	107	45	221	613	14
459026	GS	3236	19.1	97	3.3	366	178	126	111	44	219	613	14
459027	GS	3291	17.5	92	3.1	366	177	136	110	44	230	603	14
459028	GR	3801	19.4	97	2.3	354	181	147	105	48	270	565	13
459029	GR	3666	19.3	96	3.0	354	181	138	108	46	231	603	13
459030	GR	3640	18.5	95	2.3	357	180	137	104	46	261	576	13
459031	GR	3795	18.6	97	2.5	353	183	144	105	48	263	571	13
459032	GR	3738	18.0	104	2.8	355	183	147	101	45	239	602	12
459033	GR	3698	20.3	95	2.5	350	181	142	99	44	239	605	13
459034	GR	3847	17.6	99	2.7	358	182	139	110	47	238	592	13
459035	GR	3853	20.6	100	2.5	353	181	149	107	46	258	575	13
459036	GR	3732	16.1	94	2.6	357	183	139	106	43	233	606	13
459037	GR	3562	18.0	94	2.3	366	174	129	105	43	217	622	13
459038	GR	3614	17.8	90	2.0	364	176	124	111	42	214	620	14
459039	GR	3705	17.8	93	2.6	359	176	125	99	44	235	608	13
459040	GR	3359	14.3	89	2.4	353	181	125	98	41	221	627	13
459041	GR	3278	18.2	90	2.5	358	176	119	107	41	219	619	14
459042	GR	3599	20.8	96	2.5	357	176	128	101	44	232	609	14
459043	GR	3467	18.0	92	2.5	360	179	131	103	45	232	607	13
459044	GR	3725	19.7	99	2.3	355	179	123	103	43	219	621	13
459045	GR	3504	20.4	96	2.3	364	174	120	100	44	230	613	13

Table A6. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
459046	GR	3477	18.8	97	2.8	370	179	130	107	45	232	602	13
459047	GR	3356	19.3	92	2.5	370	176	136	106	45	228	607	14
459048	GR	3643	22.1	104	2.6	366	176	149	107	45	222	611	14
459049	GR	3557	22.5	97	2.5	367	173	145	105	45	242	594	14
459050	GR	3642	22.0	98	3.0	358	182	134	104	43	221	618	13
459051	GR	3456	21.4	101	2.9	364	178	131	106	45	224	611	13
459052	GR	3553	19.9	102	2.6	369	177	140	111	47	236	592	14
459053	GR	3497	23.1	102	2.8	366	176	135	101	48	235	602	14
459054	GR	3447	22.8	98	2.9	368	178	137	102	44	229	610	14
459055	BC2-YT (GT)	3842	20.7	100	2.4	363	177		104	45	245	593	13
459056	BC2-YT (GT)	3713	18.8	90	2.3	358	186		106	45	236	600	13
459057	BC2-YT (GT)	3684	20.6	95	2.2	359	178		98	42	209	638	14
459058	BC2-YT (GT)	3637	19.8	100	2.5	366	172		102	42	222	620	13
459059	BC2-YT (GT)	3775	23.5	94	2.7	363	178		99	43	238	601	19
459060	BC2-YT (GT)	3576	23.5	100	2.9	364	177		109	46	229	602	14
459061	IA3028 (GS)	3632	18.2	97	2.4	362	177	131	102	44	232	609	13
459062	IA3028 (GS)	3486	18.8	91	2.7	361	178		103	45	237	602	13
459063	IA3028 (GS)#	3607	18.9	92	2.4	363	176		104	44	233	605	13
459064	IA3028 (GS)#	3401	18.9	91	2.5	361	177		103	45	234	604	14
459065	BC3-bulk (GT)#	3387	19.5	100	2.6	358	180		102	43	233	609	13
459066	BC3-bulk (GT)#	3436	19.6	99	2.5	356	180		102	43	231	611	14
459067	BC3-bulk (GT)#	3437	19.8	98	2.6	357	181		102	44	241	600	13
459068	CSR2522N (GT)	3604	16.3	87	1.5	355	185		115	43	234	532	76
459069	CSR2682N (GT)	3986	19.6	88	1.5	354	185		104	38	212	567	79

Table A6. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score§	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
459070	CSR3242N (GT)	3968	23.6	95	1.8	351	190		116	40	258	518	68
SEM††		94.8	0.5	2.0	0.1	1.2	0.9	2.0	0.7	0.9	4.7	5.0	0.2
LSD 0.05††		264.8	1.3	5.6	0.4	3.4	2.4	5.7	1.9	2.5	13.0	13.9	0.5
LSD 0.01††		349.5	1.7	7.4	0.5	4.4	3.2	7.5	2.6	3.3	17.2	18.4	0.7

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 459055 through 459070 were not included in this calculation.

Table A7. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA3041BC, the recurrent parent, and check entries grown in four Iowa environments in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days‡	cm	score§	g kg^{-1}¶	g kg^{-1}¶	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
460001	GS	3353	29.8	96	3.6	358	169	132	106	43	261	577	13
460002	GS	3566	28.4	89	3.0	349	172	129	109	40	244	594	13
460003	GS	3361	28.0	92	2.8	352	173	126	109	38	241	598	13
460004	GS	3483	27.4	96	3.1	348	174	125	110	41	242	593	13
460005	GS	3535	28.3	98	3.0	356	175	131	110	43	250	584	14
460006	GS	3410	28.3	94	2.7	349	175	130	110	41	240	597	13
460007	GS	3586	30.5	97	3.1	352	174	136	110	41	267	569	13
460008	GS	3535	28.7	97	2.9	352	174	139	111	40	238	598	13
460009	GS	3347	29.1	93	3.7	356	168	134	110	39	252	585	13
460010	GS	3692	30.1	91	2.2	345	169	129	109	41	237	601	13
460011	GS	3813	29.1	96	2.0	345	179	147	109	44	253	582	13
460012	GS	3623	29.7	95	2.2	346	173	143	111	42	238	595	13
460013	GS	3698	29.8	90	2.0	346	168	138	107	35	230	615	13
460014	GS	3734	28.0	97	2.0	358	173	140	110	38	240	598	13
460015	GS	3709	29.8	99	2.3	348	171	140	108	43	252	583	13
460016	GS	3755	29.0	97	2.5	345	174	140	108	40	238	600	14
460017	GS	3651	28.5	94	1.9	343	172	133	108	37	241	601	13
460018	GS	3802	29.8	94	2.4	348	176	140	111	44	255	577	13
460019	GS	3598	28.8	100	2.2	349	178	138	113	44	241	589	13
460020	GS	3552	29.0	100	2.7	347	173	145	109	42	248	588	13
460021	GS	3681	26.8	98	1.9	350	175	141	108	44	256	580	13

Table A7. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
460022	GS	3568	27.3	102	2.0	349	170	145	107	41	268	572	13
460023	GS	3764	26.6	102	2.1	348	174	143	107	41	251	588	13
460024	GS	3623	29.7	102	2.2	351	172	139	109	43	244	591	13
460025	GS	3477	29.0	99	2.3	345	174	132	110	43	231	603	13
460026	GS	3604	29.3	104	2.4	351	171	148	105	42	263	577	13
460027	GS	3523	28.1	96	1.9	355	170	143	113	42	237	595	13
460028	GR	3558	28.0	93	2.9	354	173	137	113	38	245	590	13
460029	GR	3275	28.3	94	3.6	349	175	120	114	41	219	614	13
460030	GR	3551	29.5	96	2.4	349	172	138	109	39	260	578	13
460031	GR	3495	28.8	96	2.7	349	174	131	110	40	241	596	13
460032	GR	3545	29.5	100	2.6	352	175	136	111	43	261	572	13
460033	GR	3541	29.2	95	3.0	351	177	142	110	41	256	580	13
460034	GR	3485	29.5	96	2.8	350	173	143	107	36	261	584	13
460035	GR	3397	27.8	95	2.6	352	172	138	113	42	238	593	14
460036	GR	3344	28.0	93	3.0	358	168	136	110	36	252	588	14
460037	GR	3954	29.0	97	2.1	347	171	141	110	38	234	605	13
460038	GR	3880	30.4	96	2.1	346	179	148	111	45	249	583	13
460039	GR	3804	28.3	102	1.9	353	174	151	107	36	254	590	13
460040	GR	3683	29.7	99	2.5	351	173	140	108	37	246	596	13
460041	GR	3680	29.4	99	2.0	350	171	145	109	40	246	591	13
460042	GR	3729	30.4	99	2.4	354	169	146	107	40	253	587	13
460043	GR	3723	29.9	97	2.4	348	178	148	110	45	245	588	13
460044	GR	3794	28.6	98	2.2	348	176	147	110	44	246	588	13
460045	GR	3740	29.0	99	2.5	352	170	144	105	36	249	596	13

Table A7. Continued.

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
460046	GR	3524	29.5	107	2.7	350	175	145	107	44	252	584	13
460047	GR	3591	29.3	103	2.5	353	173	152	105	41	252	589	13
460048	GR	3677	27.0	101	2.3	348	172	141	107	41	246	593	13
460049	GR	3640	28.7	107	2.4	348	174	145	108	43	257	579	13
460050	GR	3612	28.3	102	2.4	344	169	142	108	40	239	600	13
460051	GR	3525	29.4	103	2.3	347	174	141	108	42	239	598	13
460052	GR	3718	28.4	101	2.2	349	175	149	110	41	246	590	13
460053	GR	3728	29.5	101	2.3	351	174	153	107	43	255	582	13
460054	GR	3646	28.3	94	1.6	346	170	144	104	39	252	592	12
460055	BC2-YT (GT)	3756	28.2	106	2.4	354	174		108	42	256	582	13
460056	BC2-YT (GT)	3750	27.6	101	2.3	347	179		111	45	249	582	13
460057	IA3041 (GS)	3817	28.9	97	2.2	350	177	138	110	41	246	590	13
460058	IA3041 (GS)	3913	28.6	95	2.4	348	177		109	40	252	586	13
460059	IA3041 (GS)#	3722	28.8	95	2.1	350	176		108	40	243	596	13
460060	IA3041 (GS)#	3729	28.9	93	2.0	348	176		108	41	251	587	13
460061	BC3-bulk (GT)#	3624	29.8	95	2.2	350	177		109	41	252	585	12
460062	BC3-bulk (GT)#	3694	29.7	97	2.4	352	176		108	42	247	590	13
460063	BC3-bulk (GT)#	3636	30.2	95	2.5	350	177		107	42	247	592	12
460064	BC3-bulk (GT)#	3765	29.7	96	2.3	351	177		108	42	243	595	13
460065	BC3-bulk (GT)#	3606	29.4	93	2.4	350	177		108	41	248	591	13
460066	BC3-bulk (GT)#	3604	29.6	95	2.4	351	177		108	41	250	588	13
460067	BC3-bulk (GT)#	3531	30.2	96	2.5	350	176		109	41	251	587	13
460068	CSR2952N	3592	22.6	92	1.8	353	178		114	41	225	543	78
460069	CSR3132N	3648	22.8	94	1.7	362	182		112	38	205	567	78

Table A7. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score§	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
460070	CSR3432N	3791	27.9	99	1.6	339	187		103	41	217	563	76
SEM††		98.8	0.4	2.2	0.1	1.0	0.6	1.9	0.7	0.6	4.8	4.7	0.2
LSD 0.05††		276.1	1.1	6.1	0.4	2.8	1.8	5.4	1.9	1.7	13.5	13.2	0.6
LSD 0.01††		364.4	1.5	8.1	0.5	3.8	2.4	7.1	2.5	2.2	17.8	17.4	0.8

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 460055 through 460070 were not included in this calculation.

APPENDIX B

ANALYSES OF VARIANCE FOR SEED TRAITS ATINDIVIDUAL ENVIRONMENTS FOR GLYPHOSATE-TOLERANT AND GLYPHOSATE-SUSCEPTIBLE LINES

Table B1. Analyses of variance for traits measured in the IA2079BC experiment at Ames, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})
Replications	2	534844.1*	1.1ns‡	226.1**	0.0ns	593.5**	74.9**
Genotypes	53	169938.6ns	6.4**	62.3ns	0.1ns	73.0**	33.7**
GS	26	173473.3ns	8.9**	54.5ns	0.0ns	56.3**	21.9**
GT	26	159212.4ns	4.1ns	63.1ns	0.1ns	92.4**	46.6**
GS vs. GT	1	1.6ns	0.1ns	242.0*	0.0ns	1.6ns	5.6ns
Error	83	144943.5	3.3	43.9	0.1	21.8	9.6
CV (%)		10.5	12.3	8.1	23.2	1.3	1.7

		Mean Squares					
Sources of Variation	df	Seed weight (mg seed^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	80.7ns	20.0*	0.9ns	98.7ns	199.1ns	2.7*
Genotypes	53	132.2**	7.3*	13.7**	421.6**	412.0*	0.5ns
GS	26	147.5**	8.9**	11.6*	592.3**	562.2**	0.5ns
GT	26	118.8**	6.0ns	16.3**	263.5ns	272.7ns	0.6ns
GS vs. GT	1	86.0ns	0.2ns	2.5ns	94.9ns	131.6ns	1.4ns
Error	83	42.5	4.2	6.8	205.0	237.7	0.7
CV (%)		4.8	1.9	5.9	5.7	6.1	7.3

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table B2. Analyses of variance for traits measured in the IA2079BC experiment at Carlisle, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})
Replications	2	2309329.9**	8.3**	456.0**	0.0ns‡	708.7**	94.6**
Genotypes	53	222871.3**	2.5**	51.0**	0.4**	100.4**	23.2**
GS	26	245677.7*	2.9**	43.0*	0.3ns	81.7**	17.2**
GT	26	204913.7*	2.1**	60.1**	0.4**	120.5**	27.0**
GS vs. GT	1	96800.0ns	1.6ns	22.2ns	1.5**	63.0*	83.1**
Error	106	125157.7	0.8	24.9	0.2	13.5	5.0
CV (%)		7.9	5.9	5.1	19.7	1.0	1.2

		Mean Squares					
Sources of Variation	df	Seed weight (mg seed^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	1556.2**	25.9**	0.0ns	2773.6**	2244.1**	0.9*
Genotypes	53	203.8**	6.5**	7.9**	622.3**	614.5**	0.5**
GS	26	236.0**	5.3**	7.1**	633.7**	606.4**	0.6**
GT	26	178.8**	7.8**	9.0**	633.6**	644.7**	0.4ns
GS vs. GT	1	17.3ns	3.6ns	2.2ns	31.1ns	37.5ns	0.0ns
Error	106	52.2	2.8	2.6	203.8	179.2	0.3
CV (%)		4.8	1.5	3.8	5.5	2.3	4.5

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table B3. Analyses of variance for traits measured in the IA2079BC experiment at Rippey, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})
Replications	2	118942.2ns‡	13.4**	6.7ns	0.0ns	42.2**	52.8**
Genotypes	53	140799.7*	3.5**	56.6**	0.1ns	92.2**	47.6**
GS	26	132208.2ns	4.9**	63.3**	0.1ns	72.9**	25.5**
GT	26	145995.4*	2.3ns	49.8**	0.1ns	109.4**	109.4**
GS vs. GT	1	229089.3ns	0.1ns	59.3ns	0.0ns	148.3**	119.3**
Error	106	84335.9	1.6	20.3	0.1	8.1	3.0
CV (%)		9.2	7.6	5.5	18.8	0.8	1.0

		Mean Squares					
Sources of Variation	df	Seed weight (mg seed^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	24.3ns	8.5*	10.1ns	477.9*	676.3**	4.0**
Genotypes	53	135.5**	8.0**	14.3**	373.1**	398.2**	0.9**
GS	26	142.6**	9.7**	15.7**	414.9**	452.5**	0.9**
GT	26	129.8**	5.9**	12.7**	345.7**	355.9**	0.8**
GS vs. GT	1	102.7*	18.0**	21.5*	0.0ns	90.4ns	0.1ns
Error	106	23.6	2.6	4.3	121.4	128.3	0.4
CV (%)		3.9	1.5	4.5	4.3	1.9	5.4

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table B4. Analyses of variance for traits measured in the IA2079BC experiment at Winterset, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})
Replications	2	370551.8**	15.1**	909.0**	0.6**	372.8**	16.6**
Genotypes	53	42392.2**	4.0**	60.2ns	0.2**	88.8**	37.5**
GS	26	43309.4**	4.4**	43.3ns	0.2**	76.9**	22.0**
GT	26	43105.1*	3.7**	77.6ns	0.2**	104.2**	53.4**
GS vs. GT	1	9.4ns	0.2ns	53.5ns	0.0ns	1.2ns	26.9ns
Error	106	23764.4	0.8	53.5	0.1	9.6	3.1
CV (%)		4.3	5.1	8.1	19.6	0.8	1.0

		Mean Squares					
Sources of Variation	df	Seed weight (mg seed^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	991.6**	19.6*	18.4**	524.9**	893.7**	1.0ns
Genotypes	53	168.3**	14.6**	8.7**	315.5**	315.2**	0.9**
GS	26	180.7**	25.4**	7.8**	309.4**	358.4**	1.0**
GT	26	154.5**	4.1ns	10.0**	333.3**	283.7**	0.8ns
GS vs. GT	1	204.5*	3.3ns	1.8ns	8.9ns	12.0ns	1.2ns
Error	106	34.9	5.6	3.7	106.8	116.4	0.5
CV (%)		4.5	2.2	4.6	4.1	1.8	5.9

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table B5. Analyses of variance for traits measured in the IA3028BC experiment at Ames, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})
Replications	2	1095950.5**	5.0*	421.0**	0.5ns	114.0**	31.1**
Genotypes	53	171742.3**	14.0**	116.2**	0.7**	131.8**	31.2**
GS	26	271341.0**	15.2**	114.1**	1.0**	118.7**	25.9**
GT	26	70582.2ns	13.1**	84.5ns	0.4**	147.9**	36.9**
GS vs. GT	1	212334.7ns	2.7ns	997.6**	0.0ns	54.5ns	20.7*
Error	92	78895.3	1.6	52.8	0.2	13.9	4.1
CV (%)		7.7	6.8	7.9	18.4	1.0	1.1

		Mean Squares					
Sources of Variation	df	Seed weight (mg seed^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	107.0ns	24.7**	39.4ns	227.1ns	456.4ns	3.4**
Genotypes	53	232.9**	40.1**	20.5ns	1012.4**	1254.3**	0.8**
GS	26	242.0**	35.1**	20.0ns	1432.0**	1651.8**	0.8**
GT	26	228.6**	46.6**	20.9ns	619.7**	890.5**	0.9**
GS vs. GT	1	110.8ns	2.7ns	22.2ns	312.5ns	379.7ns	0.3ns
Error	92	39.3	5.4	15.1	316.5	383.3	0.4
CV (%)		4.7	2.3	8.5	7.5	3.3	4.5

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table B6. Analyses of variance for traits measured in the IA3028BC experiment at Carlisle, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g $kg^{-6.21}$)	Oil (g kg^{-1})
Replications	2	1133809.1**	5.8ns	234.3**	2.1**	6.2ns	9.3ns
Genotypes	53	414367.6**	23.6**	83.7**	0.8**	100.2**	20.2**
GS	26	557289.1**	23.1**	77.8**	1.1**	99.0**	22.0**
GT	26	286271.5**	24.6**	81.9**	0.4**	102.7**	16.9**
GS vs. GT	1	28906.8ns	10.4*	282.7**	1.5**	66.8*	58.1**
Error	106	128111.4	2.0	38.4	0.1	11.4	3.7
CV (%)		9.0	7.8	6.3	12.3	0.9	1.0

		Mean Squares					
Sources of Variation	df	Seed weight (mg $seed^{-1}$)	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	1585.8**	7.6ns	81.3**	2047.3**	2412.8**	3.1**
Genotypes	53	414.9**	38.3**	10.9*	1375.5**	1457.5**	1.0*
GS	26	375.2**	37.3**	10.6ns	1721.1**	1715.9**	1.3**
GT	26	470.3**	40.8**	11.5*	1082.8**	1254.5**	0.5ns
GS vs. GT	1	8.0ns	0.7ns	0.6ns	0.0ns	17.3ns	4.5**
Error	106	29.3	6.5	7.0	230.1	246.2	0.6
CV (%)		3.8	2.4	6.1	6.2	2.6	5.8

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table B7. Analyses of variance for traits measured in the IA3028BC experiment at Rippey, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})
Replications	2	239841.9*	3.9ns	102.3**	0.2ns	147.3**	74.2**
Genotypes	53	110760.4ns	13.5**	90.6**	0.3**	126.6**	39.5**
GS	26	114743.5ns	16.0**	98.1**	0.3**	130.9**	39.1**
GT	26	108735.0ns	11.6**	75.5**	0.3**	128.6**	38.5**
GS vs. GT	1	59858ns	0.9ns	288.0**	1.0**	122.7**	77.4**
Error	106	76035.9	1.3	18.2	0.1	12.9	5.4
CV (%)		8.3	6.0	4.5	15.8	1.0	1.3

		Mean Squares					
Sources of Variation	df	Seed weight (mg seed^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	559.3**	43.2**	9.4ns	640.1*	547.7ns	6.5**
Genotypes	53	300.7**	34.8**	27.9**	1304.0**	1511.7**	0.9**
GS	26	337.1**	35.2**	29.4**	1493.6**	1689.4**	0.8**
GT	26	234.3**	35.1**	27.4**	1164.1**	1392.1**	1.0**
GS vs. GT	1	1078.5**	14.2ns	0.2ns	9.9ns	0.1ns	0.0ns
Error	106	40.4	7.5	7.2	140.3	180.1	0.4
CV (%)		4.9	2.6	5.7	5.1	2.2	4.6

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table B8. Analyses of variance for traits measured in the IA3028BC experiment at Winterset, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})
Replications	2	213344.2**	40.0**	652.1**	1.0**	84.3**	2.5ns
Genotypes	53	35172.0**	15.0**	82.3**	0.5**	113.7**	37.7**
GS	26	32229.9**	18.7**	80.9*	0.7**	102.4**	28.9**
GT	26	39455.3**	11.6**	85.1**	0.3ns	121.3**	44.5**
GS vs. GT	1	304.2ns	9.4**	47.8ns	0.0ns	206.7**	90.4**
Error	106	16296.7	1.3	42.8	0.2	5.4	4.1
CV (%)		3.7	5.4	6.9	16.7	0.6	1.2

		Mean Squares					
Sources of Variation	df	Seed weight (mg seed^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	305.8**	9.8ns	16.2*	423.2ns	693.6*	2.1**
Genotypes	53	247.1**	45.2**	10.9**	677.7**	705.8**	1.2**
GS	26	289.7**	44.1**	11.8**	962.8**	924.6**	1.1**
GT	26	209.4**	47.5**	10.2**	414.7**	503.7**	1.2**
GS vs. GT	1	115.8ns	12.0ns	7.1ns	105.9ns	272.2ns	0.6ns
Error	106	40.5	4.6	4.8	144.2	170.3	0.3
CV (%)		4.9	2.0	5.0	5.4	2.1	4.2

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table B9. Analyses of variance for traits measured in the IA3041BC experiment at Ames, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})
Replications	2	1135727.5**	9.6*	1097.6**	4.6**	83.8*	27.8**
Genotypes	53	145345.1ns	7.0**	88.7*	0.8**	43.9**	20.6**
GS	26	115309.6ns	6.7**	122.6**	1.0**	63.3**	26.6**
GT	26	179865.1ns	7.1**	57.6ns	0.6**	25.7ns	15.2**
GS vs. GT	1	28746.7ns	12.5*	15.4ns	0.1ns	14.2ns	4.5ns
Error	93	124955.8	2.4	54.0	0.3	18.7	5.0
CV (%)		9.4	5.2	7.4	18.5	1.2	1.3

		Mean Squares					
Sources of Variation	df	Seed weight (mg seed^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	6.5ns	49.6**	7.6ns	2044.8**	1710.2**	0.4ns
Genotypes	53	163.5**	15.6**	26.7**	396.9*	381.5ns	0.6ns
GS	26	104.4**	14.3**	25.0**	363.9ns	378.4ns	0.3ns
GT	26	196.7**	16.3**	28.7**	440.1*	399.1ns	0.9*
GS vs. GT	1	845.1**	33.8*	20.1ns	128.0ns	0.7ns	0.1ns
Error	93	48.6	4.9	6.8	249.4	275.0	0.5
CV (%)		4.9	2.1	6.3	6.5	2.8	5.5

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table B10. Analyses of variance for traits measured in the IA3041BC experiment at Carlisle, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})
Replications	2	739037.5**	8.7**	107.6**	0.3ns	53.2**	84.0**
Genotypes	53	310885.8**	3.8**	106.1**	0.8**	36.6**	28.8**
GS	26	289727.6**	5.3**	101.4**	1.0**	49.0**	24.6**
GT	26	332763.2**	2.4**	90.6**	0.7**	25.1**	33.2**
GS vs. GT	1	292187.7ns	0.2ns	632.1**	0.0ns	11.4ns	23.0**
Error	106	100140.6	1.0	34.2	0.1	8.6	2.8
CV (%)		7.6	4.1	5.9	12.5	0.8	1.0

		Mean Squares					
Sources of Variation	df	Seed weight (mg seed^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	431.4**	1.2ns	20.0**	2638.6**	13.6**	1.5**
Genotypes	53	228.1**	16.5**	18.2**	608.6**	513.0**	1.0**
GS	26	203.0**	16.5**	16.1**	692.6**	620.1**	0.9*
GT	26	192.4**	17.1**	20.1**	540.9**	424.3*	1.0**
GS vs. GT	1	1806.7**	2.7ns	22.2ns	186.9ns	34.7ns	0.7ns
Error	106	30.6	3.4	6.2	255.7	224.4	0.5
CV (%)		4.0	1.7	6.4	6.0	2.6	5.2

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table B11. Analyses of variance for traits measured in the IA3041BC experiment at Rippey, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})
Replications	2	1242197.1**	13.4**	507.0**	3.0**	2.7ns	197.3**
Genotypes	53	90443.3ns	1.8**	84.8**	0.6**	51.1**	29.3**
GS	26	86167.0ns	1.8**	85.4**	0.8**	70.7**	29.8**
GT	26	94590.8ns	1.8**	80.1**	0.4**	33.4**	27.0**
GS vs. GT	1	93792.6ns	0.5ns	191.2*	0.0ns	0.2ns	26.9*
Error	106	75985.4	0.5	30.8	0.2	17.1	5.1
CV (%)		8.6	2.5	5.6	23.5	1.2	1.3

		Mean Squares					
Sources of Variation	df	Seed weight (mg seed^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	35.6ns	2.0ns	0.0ns	868.6**	982.0**	2.6**
Genotypes	53	164.3**	22.3**	20.6**	337.6**	358.5**	0.7**
GS	26	125.1**	16.1**	18.2**	372.8**	413.3**	0.6ns
GT	26	172.7**	29.2**	23.5**	311.3*	315.9**	0.6ns
GS vs. GT	1	963.1**	5.2ns	9.4ns	104.3ns	40.5ns	2.7**
Error	106	26.6	4.1	4.4	171.8	190.8	0.4
CV (%)		3.9	1.9	5.0	5.6	2.3	4.7

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns = not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

Table B12. Analyses of variance for traits measured in the IA3041BC experiment at Winterset, IA, in 2010.

		Mean Squares					
Sources of Variation†	df	Yield (kg ha^{-1})	Maturity (d§)	Height (cm)	Lodging (score¶)	Protein (g kg^{-1})	Oil (g kg^{-1})
Replications	2	167122.3**	2.5*	2139.6**	8.8**	324.2**	3.1ns
Genotypes	53	54817.3**	3.1**	80.6ns	0.9**	56.9**	23.5**
GS	26	48071.3**	3.4**	75.6ns	1.0**	65.7**	21.4**
GT	26	59004.1**	2.9**	84.5ns	0.9**	50.3**	26.6**
GS vs. GT	1	121360.2*	0.0ns	107.6ns	0.0ns	1.8ns	0.0ns
Error	106	20049.7	0.6	59.0	0.3	8.7	3.7
CV (%)		4.3	2.6	8.2	20.8	0.8	1.1

		Mean Squares					
Sources of Variation	df	Seed weight (mg seed^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
Replications	2	1513.4**	10.2ns	9.1ns	3548.0**	3423.0**	4.4**
Genotypes	53	176.0**	15.9**	25.6**	632.9**	692.1**	0.7**
GS	26	153.3**	13.3**	21.5**	687.4**	778.5**	0.5ns
GT	26	176.1**	18.8**	27.7**	602.4*	629.1*	0.9**
GS vs. GT	1	760.5**	8.9ns	80.2**	9.4ns	83.1ns	1.0ns
Error	106	25.7	4.9	4.4	354.5	332.0	0.4
CV (%)		3.5	2.0	5.2	7.3	3.1	4.7

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.
‡ ns = not significant at the 0.05 probability level.
§ Days after 31 August.
¶ Score ranged from 1 (all plants erect) to 5 (all plants prostrate).

APPENDIX C

TYPE AND ENTRY MEANS FOR SEED TRAITS AT INDIVIDUAL ENVIRONMENTS

Table C1. Mean and range for agronomic and seed traits of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of the IA2079BC experiment at four Iowa environments in 2010.

		Ames		Carlisle		Rippey		Winterset	
Trait	Type†	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Yield	GS	3573	3033-4181ns	4489	3738-5112*	3110	2611-3446ns	3592	3286-3860**
(kg ha^{-1})	GR	3667ns‡	3143-4186ns	4440ns	3906-4885*	3185ns	2756-3802*	3593ns	3324-3835*
Maturity	GS	14.8	11.3-17.7**	15.5	13.3-17.0**	16.6	14.7-19.0**	18.2	16.0-20.0**
(d§)	GR	14.8ns	12.7-17.3ns	15.7ns	14.0-17.0**	16.6ns	15.0-18.0ns	18.0ns	15.7-20.0**
Height	GS	80	71-87ns	98	91-104*	82	70-91**	89	79-96ns
(cm)	GR	82*	75-92ns	99ns	89-106**	83ns	77-91**	90ns	79-99ns
Lodging	GS	1.4	1.2-2.7ns	2.0	1.5-2.7ns	1.2	1.0-1.5ns	1.6	1.0-2.2**
(score¶)	GR	1.4ns	1.0-1.8ns	2.2**	1.5-2.8**	1.2ns	1.0-1.5ns	1.6ns	1.0-2.0**
Protein	GS	362	354-371**	367	357-378**	363	351-372**	374	364-382**
(g kg^{-1}#)	GR	362ns	353-371**	366*	356-377**	361**	350-373**	374ns	365-384**
Oil	GS	183	178-189**	182	178-188**	181	175-187**	174	169-180**
(g kg^{-1}#)	GR	184ns	178-192**	184**	179-191**	182**	174-192**	175ns	167-183**
Seed Wt.	GS	133	117-145**	151	134-162**	123	109-135**	132	115-153**
(mg sd^{-1})	GR	131ns	123-146**	151ns	139-164**	125*	113-139**	134*	118-146**
Palmitate	GS	106	103-110**	110	106-113**	108	103-111**	109	105-120**
(g kg^{-1})	GR	107ns	103-110ns	110ns	107-113**	107**	105-110**	108ns	106-110ns
Stearate	GS	44	40-49*	42	38-45**	46	41-52**	42	38-45**
(g kg^{-1})	GR	44ns	40-49**	43ns	39-46**	46*	43-50**	42ns	38-46**
Oleate	GS	252	225-290**	261	228-287**	255	234-279**	250	217-266**
(g kg^{-1})	GR	251ns	233-269ns	262ns	231-293**	255ns	235-278**	250ns	222-268**
Linoleate	GS	585	551-611**	575	551-609**	579	555-600**	588	569-623**
(g kg^{-1})	GR	587ns	569-603ns	574ns	546-603**	580ns	558-598**	588ns	571-614**
Linolenate	GS	11	11-12ns	11	10-12**	12	11-13**	12	11-13**
(g kg^{-1})	GR	12ns	11-13ns	11ns	11-12ns	12ns	11-13**	12ns	11-14ns

* Significant at the 0.05 probability level between means of the two types or among lines within a type.

** Significant at the 0.01 probability level between means of the two types or among lines within a type.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns, difference between the means of the two types or among lines within a type were not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Table C2. Mean and range for agronomic and seed traits of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of the IA3028BC experiment at four Iowa environments in 2010.

		Ames		Carlisle		Rippey		Winterset	
Trait	Type†	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Yield	GS	3612	2683-4100**	4011	3001-4699**	3341	2946-3683ns	3432	3248-3604**
(kg ha^{-1})	GR	3684ns‡	3370-3957ns	3985ns	3418-4587**	3303ns	2917-3572ns	3429ns	3269-3684**
Maturity	GS	18.7	12.7-23.3**	17.7	12.0-22.7**	18.9	14.0-23.7**	21.1	15.3-25.7**
(d§)	GR	19.0ns	13.0-22.3**	18.2*	13.0-25.0**	19.1ns	14.3-24.3**	21.6**	17.0-25.3**
Height	GS	90	75-102**	97	83-107**	93	80-105**	94	83-106*
(cm)	GR	95**	87-110ns	100**	91-109**	96**	84-107**	95ns	85-105**
Lodging	GS	2.6	1.8-4.0**	3.0	2.2-4.3**	1.6	1.0-2.2**	2.7	1.8-3.5**
(score¶)	GR	2.6ns	2.0-3.5**	3.2**	2.5-3.8**	1.7**	1.0-2.3**	2.7ns	2.0-3.3ns
Protein	GS	361	349-375**	361	350-374**	356	345-372**	370	360-382**
(g kg^{-1}#)	GR	359ns	348-370**	359*	349-372**	355**	345-366**	367**	358-378**
Oil	GS	180	174-186**	180	174-186**	178	173-186**	171	165-178**
(g kg^{-1}#)	GR	180*	174-187**	181**	175-185**	180**	174-186**	173**	166-179**
Seed Wt.	GS	133	118-151**	142	124-163**	128	111-156**	130	117-149**
(mg sd^{-1})	GR	132Ns	116-149**	142ns	122-167**	133**	117-152**	131ns	115-146**
Palmitate	GS	103	97-110**	106	100-112**	104	98-109**	106	99-114**
(g kg^{-1})	GR	103ns	96-110**	106ns	99-114**	103ns	96-110**	105ns	98-114**
Stearate	GS	46	41-50ns	43	41-48ns	47	41-53**	43	40-48**
(g kg^{-1})	GR	46ns	41-51ns	43ns	39-46*	47ns	42-53**	43ns	40-46**
Oleate	GS	237	198-278**	245	208-284**	234	196-295**	225	199-269**
(g kg^{-1})	GR	235ns	213-268**	245ns	216-286**	234ns	205-288**	223ns	202-253**
Linoleate	GS	600	554-643**	592	560-632**	602	542-642**	612	575-637**
(g kg^{-1})	GR	603ns	561-626**	592ns	547-624**	602ns	548-635**	615ns	584-635**
Linolenate	GS	13	12-14**	13	12-15**	14	13-14**	14	12-15**
(g kg^{-1})	GR	13ns	12-14**	13**	12-14ns	14ns	12-14**	14ns	12-14**

* Significant at the 0.05 probability level between means of the two types or among lines within a type.

** Significant at the 0.01 probability level between means of the two types or among lines within a type.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns, difference between the means of the two types or among lines within a type were not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Table C3. Mean and range for agronomic and seed traits of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of the IA3041BC experiment at four Iowa environments in 2010.

		Ames		Carlisle		Rippey		Winterset	
Trait	Type†	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Yield	GS	3741	3378-4150ns	4129	3526-4617**	3212	2961-3615ns	3294	3062-3512**
(kg ha^{-1})	GR	3767ns‡	3299-4330ns	4314ns	3307-5044**	3164ns	2915-3467ns	3349*	2967-3583**
Maturity	GS	29.2	26.3-31.7**	24.8	22.3-27.3**	30.0	28.7-31.3**	31.0	29.0-33.3**
(d§)	GR	28.8*	27.0-32.3**	24.9ns	23.3-26.7**	30.1ns	27.7-31.3**	31.0**	29.0-32.3**
Height	GS	99	87-109**	98	85-108**	97	87-107**	92	82-101ns
(cm)	GR	99ns	91-106ns	101**	91-117**	99*	87-111**	94ns	83-105ns
Lodging	GS	2.9	2.0-4.2**	2.8	1.7-4.0**	1.7	1.2-3.2**	2.5	1.7-3.7**
(score¶)	GR	2.9ns	1.8-4.2**	2.8ns	2.0-4.0**	1.7ns	1.0-2.7**	2.5ns	1.5-3.7**
Protein	GS	349	342-359**	348	341-356**	341	333-351**	360	353-372**
(g kg^{-1}#)	GR	350ns	342-355ns	349ns	356-357**	341ns	335-349**	360ns	352-370**
Oil	GS	174	170-181**	175	169-180**	174	168-181**	168	162-173**
(g kg^{-1}#)	GR	175ns	170-179**	176**	169-183**	174*	169-181**	168ns	162-174**
Seed Wt.	GS	145	131-151**	136	120-150**	131	116-143**	142	128-155**
(mg sd^{-1})	GR	140**	121-157**	143**	116-158**	136**	123-154**	146**	122-156**
Palmitate	GS	107	101-111**	112	109-117**	108	104-113**	109	105-113**
(g kg^{-1})	GR	106*	101-111**	112ns	108-117**	109ns	103-116**	108ns	103-114**
Stearate	GS	42	36-48**	39	32-44**	43	36-46**	41	35-45**
(g kg^{-1})	GR	41ns	36-47**	39ns	34-43**	42ns	37-47**	40**	34-44**
Oleate	GS	244	223-270ns	251	228-279**	233	212-259**	259	235-300**
(g kg^{-1})	GR	245ns	227-280*	253ns	219-285**	234ns	208-251*	259ns	216-287*
Linoleate	GS	594	573-624ns	584	559-612**	603	575-622**	579	538-603**
(g kg^{-1})	GR	594ns	567-618ns	583ns	558-611*	602ns	583-629**	280ns	547-616*
Linolenate	GS	13	12-14ns	13	12-15*	13	12-14ns	13	12-14ns
(g kg^{-1})	GR	13ns	12-14*	13ns	12-15**	13**	12-14ns	13ns	12-14**

* Significant at the 0.05 probability level between means of the two types or among lines within a type.

** Significant at the 0.01 probability level between means of the two types or among lines within a type.

† GS = glyphosate-susceptible lines, GT = glyphosate-tolerant lines.

‡ ns, difference between the means of the two types or among lines within a type were not significant at the 0.05 probability level.

§ Days after 31 August.

¶ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Table C4. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA2079BC, the recurrent parent, and check entries grown in Ames, IA, in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days‡	cm	score§	g kg^{-1}¶	g kg^{-1}¶	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
458001	GS	3403	14.3	72	1.3	366	181	134	108	45	263	572	12
458002	GS	3529	11.7	82	1.5	367	186	131	104	45	283	556	11
458003	GS	3033	13.7	71	1.3	360	184	117	107	44	250	587	11
458004	GS	3612	14.7	78	1.5	362	178	127	107	44	247	590	12
458005	GS	3211	12.7	81	1.5	359	186	120	104	48	262	574	12
458006	GS	3707	14.7	77	1.2	360	181	122	109	44	248	588	11
458007	GS	3356	12.3	79	1.5	363	182	131	105	44	261	579	11
458008	GS	3513	12.7	87	1.3	363	184	130	105	49	257	578	11
458009	GS	3405	15.0	77	1.3	368	178	127	107	46	262	573	12
458010	GS	3315	11.3	84	1.3	364	186	137	108	40	290	551	11
458011	GS	3647	15.0	83	1.3	366	181	136	108	41	249	589	12
458012	GS	3478	14.3	87	1.7	368	183	138	110	42	270	566	11
458013	GS	3373	17.3	77	1.3	361	181	130	107	47	251	583	12
458014	GS	3652	14.7	73	1.3	359	185	132	108	44	242	593	12
458015	GS	3664	14.7	85	1.5	355	186	136	108	42	246	593	11
458016	GS	3256	13.3	79	1.3	371	183	145	107	43	247	591	12
458017	GS	3539	16.3	80	1.5	362	182	132	107	44	240	591	11
458018	GS	3678	15.0	81	1.3	367	182	140	107	44	254	583	12
458019	GS	3850	17.0	82	1.5	356	186	129	107	44	252	585	11
458020	GS	3720	15.0	81	1.5	354	189	137	105	45	250	589	11
458021	GS	3861	17.7	83	1.5	363	179	129	103	45	233	607	12

Table C4. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458022	GS	3725	17.3	81	1.5	357	185	141	106	44	246	593	11
458023	GS	3862	15.3	82	1.5	360	185	124	106	44	233	605	11
458024	GS	4181	15.7	82	1.3	360	184	134	104	46	248	591	11
458025	GS	3573	17.0	83	1.7	365	184	141	105	44	260	580	11
458026	GS	3545	14.7	73	1.2	360	186	132	107	43	248	591	11
458027	GS	3788	16.3	79	1.3	358	182	120	109	43	225	611	12
458028	GR	3759	15.0	83	1.5	368	178	135	108	46	245	590	12
458029	GR	3468	14.3	79	1.3	368	179	128	107	41	243	598	12
458030	GR	3497	15.3	81	1.3	364	181	127	106	45	269	569	12
458031	GR	3348	14.7	79	1.2	363	180	127	106	48	253	581	12
458032	GR	3731	15.7	81	1.5	363	182	138	106	45	253	585	12
458033	GR	3375	13.0	78	1.3	368	180	138	103	49	262	575	12
458034	GR	3621	15.0	77	1.2	358	183	124	110	45	244	590	12
458035	GR	3860	14.7	80	1.7	361	179	128	107	44	245	592	12
458036	GR	3833	12.7	85	1.3	364	182	127	105	49	249	587	11
458037	GR	3631	14.0	86	1.3	369	181	144	108	41	266	575	11
458038	GR	3472	13.3	85	1.2	368	185	140	107	42	268	572	12
458039	GR	3611	13.0	91	1.7	368	184	144	106	44	265	573	12
458040	GR	3644	14.7	78	1.5	362	185	130	107	43	258	582	11
458041	GR	3666	16.3	84	1.8	370	181	146	107	41	243	598	11
458042	GR	3718	15.7	92	1.3	371	178	135	108	40	251	589	12
458043	GR	3533	14.7	91	1.5	366	182	133	107	46	261	574	12
458044	GR	3889	14.0	81	1.5	360	184	130	107	43	246	592	12
458045	GR	3487	15.0	89	1.5	366	182	129	108	41	257	578	12

Table C4. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458046	GR	4186	16.3	87	1.7	356	184	128	106	44	236	603	11
458047	GR	3638	16.7	83	1.3	354	190	141	104	46	250	588	11
458048	GR	3556	16.3	83	1.3	355	188	127	105	46	248	590	11
458049	GR	3938	15.0	81	1.3	356	190	137	107	43	251	589	11
458050	GR	3589	15.7	81	1.3	354	190	123	106	44	249	586	11
458051	GR	3143	14.7	75	1.0	353	189	134	106	42	240	601	11
458052	GR	3949	14.3	81	1.2	360	186	132	108	45	233	602	13
458053	GR	4076	17.3	78	1.2	361	184	132	107	43	246	593	11
458054	GR	3794	13.7	79	1.5	356	192	134	106	45	246	591	12
458055	BC2-YT (GT)	3587	14.3	78	1.5	361	180		106	45	261	576	11
458056	BC2-YT (GT)	2876	15.3	83	1.5	366	183		107	42	262	576	13
458057	BC2-YT (GT)	3868	17.7	78	1.5	357	185		105	44	237	602	11
458058	BC2-YT (GT)	3510	15.0	83	1.3	360	188		106	44	256	583	11
458059	BC2-YT (GT)	3644	19.0	87	1.5	355	187		104	43	263	578	11
458060	BC2-YT (GT)	3896	16.7	87	1.5	361	185		105	44	273	567	11
458061	BC2-YT (GT)	3968	14.3	83	1.8	353	189		106	43	246	594	11
458062	IA2079 (GS)	3851	13.7	85	1.5	363	184	136	106	43	249	588	11
458063	IA2079 (GS)	3722	14.7	77	1.7	362	183		106	42	253	587	11
458064	IA2079 (GS)#	3648	13.7	84	1.3	363	185		107	43	253	586	11
458065	IA2079 (GS)#	3540	15.3	81	1.5	360	186		106	42	254	586	11
458066	BC3-bulk (GS)#	3745	17.0	82	1.5	364	179		107	43	242	596	12
458067	BC3-bulk (GS)#	3737	17.0	81	1.3	363	181		108	40	234	607	11
458068	CSR2252N (GT)	2802	15.7	81	1.0	355	191		103	40	230	566	61
458069	CSR2522N (GT)	3497	17.0	79	1.2	350	188		112	43	238	534	73

Table C4. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
458070	CSR2682N (GT)	3492	20.3	77	1.0	349	186		102	38	214	567	79
SEM††		219.8	1.0	3.8	0.2	2.7	1.8	3.8	1.2	1.5	8.3	8.9	0.5
LSD 0.05††		618.3	2.9	10.8	05	7.6	5.0	10.6	3.3	4.2	23.2	25.0	1.4
LSD 0.01††		819.5	3.9	14.3	0.7	10.1	6.7	14.0	4.4	5.6	30.8	33..2	1.8

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 458055 through 458070 were not included in this calculation.

Table C5. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA2079BC, the recurrent parent, and check entries grown in Carlisle, IA, in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days‡	cm	score§	g kg^{-1}¶	g kg^{-1}¶	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
458001	GS	4313	15.7	98	1.5	369	179	150	111	43	280	555	11
458002	GS	4496	14.3	99	2.2	371	183	152	108	42	287	551	12
458003	GS	4817	15.3	97	1.8	364	185	136	111	45	254	578	11
458004	GS	4405	13.3	91	2.3	363	182	141	112	43	238	595	12
458005	GS	4460	14.3	103	1.8	365	181	141	110	43	261	574	12
458006	GS	4437	15.3	97	2.3	370	178	144	112	43	255	579	11
458007	GS	4520	14.3	97	2.2	373	182	162	109	42	275	562	11
458008	GS	3873	15.0	91	2.5	366	182	138	109	44	261	575	11
458009	GS	3738	14.0	93	2.7	369	182	147	112	43	271	563	11
458010	GS	4714	14.7	101	2.3	375	180	158	108	39	282	559	12
458011	GS	4508	15.7	104	2.2	378	179	162	110	38	271	569	12
458012	GS	4339	15.3	103	2.0	375	179	162	113	42	263	571	12
458013	GS	4162	16.3	96	1.8	364	181	153	112	44	256	577	12
458014	GS	4668	15.3	94	1.5	365	184	158	111	41	251	585	11
458015	GS	4720	16.3	99	2.5	365	183	159	110	40	271	567	11
458016	GS	4198	14.3	92	2.2	373	182	156	111	42	267	569	12
458017	GS	4555	15.7	99	2.2	366	183	162	110	43	268	568	11
458018	GS	4533	16.0	101	1.8	371	179	160	110	42	282	556	11
458019	GS	5112	17.0	101	2.0	359	187	154	108	45	266	570	11
458020	GS	4628	17.0	103	2.0	361	188	152	109	41	263	577	11
458021	GS	4625	15.7	99	2.3	363	183	134	108	43	240	598	11

Table C5. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458022	GS	4789	17.0	101	1.7	364	182	153	106	44	244	595	11
458023	GS	4520	15.7	95	2.0	360	187	145	112	41	244	593	10
458024	GS	4213	16.0	97	1.8	367	181	141	110	42	250	587	11
458025	GS	4488	17.0	99	2.0	365	182	154	110	42	260	576	11
458026	GS	4641	16.0	94	1.5	371	182	152	110	42	258	579	11
458027	GS	4740	15.7	99	1.7	357	184	139	111	42	228	609	11
458028	GR	4665	14.3	97	2.0	370	181	155	110	44	267	568	11
458029	GR	4708	15.0	99	1.7	367	180	148	110	42	268	569	12
458030	GR	4254	14.7	96	2.5	364	183	139	111	44	256	578	11
458031	GR	4254	14.0	95	2.2	365	182	139	109	43	270	566	12
458032	GR	3947	16.0	98	2.5	362	183	145	110	41	253	584	12
458033	GR	3984	14.7	91	2.5	375	179	156	107	45	288	549	12
458034	GR	4349	15.7	91	2.7	363	183	143	113	43	271	562	11
458035	GR	4399	14.7	89	2.2	367	181	144	111	46	271	561	11
458036	GR	4354	15.7	101	2.3	369	182	145	108	42	293	546	11
458037	GR	4376	16.3	102	2.5	377	180	164	112	39	261	576	12
458038	GR	4504	17.0	106	2.5	376	182	164	110	41	273	564	12
458039	GR	4173	14.0	91	2.7	370	185	150	109	45	283	552	11
458040	GR	4666	16.0	104	2.0	371	181	158	111	40	276	561	11
458041	GR	4625	16.7	99	2.5	371	182	164	110	40	260	579	11
458042	GR	4436	16.3	100	2.0	367	181	153	111	41	257	580	11
458043	GR	4615	15.7	104	2.7	372	183	159	110	44	264	570	11
458044	GR	3906	16.0	101	2.5	371	181	157	111	42	251	584	12
458045	GR	4352	16.0	102	2.8	371	183	157	111	40	270	567	11

Table C5. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458046	GR	4505	16.3	99	2.3	357	188	147	108	43	247	592	11
458047	GR	4348	16.0	101	1.8	357	190	155	107	43	248	591	11
458048	GR	4160	16.7	99	2.2	359	187	145	110	43	242	593	11
458049	GR	4885	16.0	104	2.0	363	185	160	109	42	261	577	11
458050	GR	4559	16.7	104	2.5	356	187	148	110	44	245	591	11
458051	GR	4786	15.7	99	1.5	359	186	150	110	42	251	586	11
458052	GR	4650	15.3	95	1.7	362	184	141	110	45	231	603	11
458053	GR	4778	16.0	98	1.7	359	186	142	109	42	246	591	11
458054	GR	4652	16.3	98	1.7	357	191	153	110	42	270	567	11
458055	BC2-YT (GT)	4414	15.7	99	2.5	368	179		110	42	268	569	11
458056	BC2-YT (GT)	4526	16.3	104	2.2	374	180		109	43	252	585	12
458057	BC2-YT (GT)	4556	17.7	96	2.2	355	187		109	42	239	599	11
458058	BC2-YT (GT)	4369	14.7	99	2.2	363	188		108	42	272	568	11
458059	BC2-YT (GT)	4780	18.0	99	2.0	359	184		107	43	258	580	11
458060	BC2-YT (GT)	4696	18.0	103	1.8	362	184		108	42	255	584	11
458061	BC2-YT (GT)	4708	17.0	95	2.2	358	183		110	41	244	594	11
458062	IA2079 (GS)	4261	15.0	97	2.0	365	185	141	110	43	248	588	11
458063	IA2079 (GS)	4418	16.0	100	2.0	366	184		108	43	260	578	11
458064	IA2079 (GS)#	4431	15.0	95	2.0	361	186		109	43	252	585	11
458065	IA2079 (GS)#	4461	15.3	95	2.0	363	185		108	41	262	578	11
458066	BC3-bulk (GS)#	4286	17.3	105	2.5	367	179		111	40	244	595	11
458067	BC3-bulk (GS)#	3975	19.3	92	2.5	367	180		111	42	241	596	11
458068	CSR2252N (GT)	3960	12.7	93	2.2	350	196		107	39	232	555	67
458069	CSR2522N (GT)	4071	14.7	95	2.0	354	190		117	41	238	531	72

Table C5. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
458070	CSR2682N (GT)	5104	17.7	95	1.7	347	191		105	38	228	555	74
SEM††		204.3	0.5	2.9	0.2	2.1	1.3	4.2	1.0	0.9	8.2	7.7	0.3
LSD 0.05††		572.7	1.5	8.1	0.7	6.0	3.6	11.7	2.7	2.6	23.1	21.7	0.8
LSD 0.01††		757.7	2.0	10.7	0.9	7.9	4.8	15.5	3.6	3.4	30.6	28.7	1.1

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 458055 through 458070 were not included in this calculation.

Table C6. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA2079BC, the recurrent parent, and check entries grown in Rippey, IA, in 2010.

Entry	Type†	Yield kg ha^{-1}	Maturity days‡	Height cm	Lodging score§	Protein g kg^{-1}¶	Oil g kg^{-1}¶	Seed weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458001	GS	3000	17.0	82	1.2	369	175	120	110	45	251	582	12
458002	GS	3165	15.3	81	1.0	369	179	123	103	51	278	556	12
458003	GS	3222	15.3	71	1.2	365	180	113	109	48	253	578	11
458004	GS	2969	14.7	79	1.2	359	179	109	105	48	234	600	12
458005	GS	3294	16.3	85	1.3	362	179	116	108	47	249	582	13
458006	GS	3138	17.7	83	1.5	363	177	116	109	46	245	589	12
458007	GS	3409	15.0	84	1.3	363	179	130	108	46	256	580	11
458008	GS	3163	15.0	82	1.3	366	179	117	106	47	269	567	11
458009	GS	3112	17.0	87	1.2	368	176	119	108	46	279	555	12
458010	GS	3178	14.7	80	1.2	372	181	134	108	43	276	561	12
458011	GS	3154	16.0	82	1.0	368	179	124	109	41	260	577	12
458012	GS	3311	17.3	84	1.5	369	179	127	110	47	255	576	12
458013	GS	3164	18.0	86	1.2	364	179	131	111	46	251	581	12
458014	GS	3122	16.3	78	1.3	360	182	122	109	43	253	580	12
458015	GS	3346	17.3	79	1.3	364	180	125	108	46	245	589	12
458016	GS	2804	15.3	82	1.0	368	184	135	107	49	267	564	12
458017	GS	3446	16.0	85	1.2	359	181	124	107	45	251	585	12
458018	GS	3379	17.0	91	1.0	368	180	131	109	44	258	578	12
458019	GS	2987	15.7	86	1.3	356	186	120	109	52	270	558	11
458020	GS	3196	18.7	81	1.0	351	187	127	106	46	239	598	12
458021	GS	2611	18.0	77	1.3	362	180	115	106	46	244	593	11

Table C6. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458022	GS	3107	18.7	82	1.3	360	184	131	105	47	252	584	12
458023	GS	2844	16.0	77	1.2	358	186	122	106	47	247	590	11
458024	GS	2941	15.7	81	1.2	360	183	119	106	47	258	578	11
458025	GS	3086	19.0	85	1.3	361	181	131	106	46	252	578	12
458026	GS	3175	17.3	87	1.2	361	181	127	109	48	260	572	12
458027	GS	2650	17.3	70	1.0	355	184	114	108	47	238	595	12
458028	GR	3148	16.7	84	1.5	363	179	125	108	45	252	583	12
458029	GR	3007	15.0	77	1.0	364	179	114	106	46	257	580	12
458030	GR	3386	15.0	81	1.3	361	182	113	105	48	263	572	12
458031	GR	3318	15.7	81	1.0	366	176	118	106	48	261	573	13
458032	GR	3115	16.3	77	1.2	359	183	119	106	45	268	570	12
458033	GR	3071	16.0	80	1.5	373	174	132	106	50	265	566	13
458034	GR	3484	16.0	81	1.2	355	182	116	110	47	235	596	12
458035	GR	3147	16.0	79	1.2	361	179	117	106	46	244	590	13
458036	GR	3309	17.3	88	1.5	365	177	121	106	48	265	569	12
458037	GR	3129	16.3	89	1.3	369	176	131	110	43	274	561	12
458038	GR	3219	16.7	89	1.3	368	182	134	107	44	258	579	12
458039	GR	3300	15.3	91	1.2	372	183	139	106	47	278	558	12
458040	GR	3169	16.0	80	1.0	363	181	125	108	44	246	590	12
458041	GR	3161	18.0	85	1.3	364	180	128	109	43	247	589	12
458042	GR	3335	16.3	88	1.3	364	178	124	107	43	245	587	12
458043	GR	3144	17.7	87	1.3	361	181	124	106	48	255	580	11
458044	GR	3143	16.3	83	1.0	358	182	131	108	43	246	592	12
458045	GR	2759	17.7	84	1.3	366	181	127	108	43	266	570	12

Table C6. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458046	GR	3211	17.7	87	1.5	352	187	121	106	46	253	584	11
458047	GR	3399	17.7	79	1.3	350	191	131	107	43	240	598	12
458048	GR	3372	17.7	83	1.2	354	188	125	106	45	253	586	11
458049	GR	2818	16.7	83	1.5	359	188	127	106	46	260	577	11
458050	GR	3021	16.0	83	1.3	353	188	118	105	47	255	581	11
458051	GR	2756	17.3	80	1.0	356	188	126	109	48	264	567	12
458052	GR	3802	17.3	77	1.0	360	185	124	107	47	244	589	12
458053	GR	3225	17.3	79	1.2	356	186	120	107	44	242	595	11
458054	GR	3057	17.0	82	1.0	354	192	132	107	45	254	583	11
458055	BC2-YT (GT)	2889	17.3	84	1.2	367	176		109	49	261	570	11
458056	BC2-YT (GT)	3284	17.7	90	1.5	364	181		108	46	257	578	11
458057	BC2-YT (GT)	3316	18.3	85	1.2	354	187		105	46	243	595	11
458058	BC2-YT (GT)	2841	16.7	85	1.2	357	187		106	47	252	582	12
458059	BC2-YT (GT)	2860	19.7	83	1.3	355	186		106	47	256	579	12
458060	BC2-YT (GT)	3202	18.3	90	1.2	357	187		106	48	269	566	11
458061	BC2-YT (GT)	2715	15.3	80	1.3	356	187		106	47	268	568	11
458062	IA2079 (GS)	3441	15.3	82	1.2	358	184	121	106	47	252	582	13
458063	IA2079 (GS)	2636	17.7	77	1.2	362	182		109	48	249	582	12
458064	IA2079 (GS)#	3303	16.7	85	1.5	359	183		106	46	268	568	12
458065	IA2079 (GS)#	3038	15.3	83	1.3	362	184		105	46	250	588	12
458066	BC3-bulk (GS)#	2969	17.3	85	1.3	363	179		108	43	240	597	12
458067	BC3-bulk (GS)#	3135	18.7	87	1.2	360	180		109	42	247	590	12
458068	CSR2252N (GT)	3301	15.0	84	1.0	352	193		103	39	219	568	71
458069	CSR2522N (GT)	2932	17.0	81	1.2	350	187		117	45	245	520	74

Table C6. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458070	CSR2682N (GT)	3070	21.7	84	1.0	351	186		103	40	220	561	76
SEM††		167.7	0.7	2.6	0.1	1.6	1.0	2.8	0.9	1.2	6.4	6.5	0.4
LSD 0.05††		470.1	2.0	7.3	0.4	4.6	2.8	7.9	2.6	3.4	17.8	18.3	1.1
LSD 0.01††		622.0	2.7	9.6	0.5	6.1	3.7	10.4	3.4	4.5	23.6	24.3	1.4

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 458055 through 458070 were not included in this calculation.

Table C7. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA2079BC, the recurrent parent, and check entries grown in Winterset, IA, in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		$kg\ ha^{-1}$	days‡	cm	score§	$g\ kg^{-1}$¶	$g\ kg^{-1}$¶	$mg\ sd^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$
458001	GS	3603	18.3	90	1.7	380	169	137	120	43	248	576	12
458002	GS	3594	16.0	85	1.5	379	173	129	107	44	266	571	12
458003	GS	3559	18.0	86	1.3	373	173	119	112	42	240	594	12
458004	GS	3544	16.0	86	1.7	373	170	121	109	43	247	589	13
458005	GS	3478	16.7	89	1.5	374	171	123	107	44	265	569	12
458006	GS	3286	17.7	83	1.3	375	171	120	111	45	255	578	12
458007	GS	3554	16.3	90	1.7	375	172	134	108	40	260	582	11
458008	GS	3612	17.3	96	1.8	373	173	128	107	42	252	587	12
458009	GS	3377	17.3	86	1.5	379	171	132	110	43	248	588	12
458010	GS	3466	16.7	94	1.7	382	173	138	107	39	257	586	12
458011	GS	3585	18.0	92	1.5	380	171	132	110	38	247	592	13
458012	GS	3488	19.0	95	1.3	381	171	134	109	40	249	589	12
458013	GS	3683	19.3	88	1.7	377	172	135	109	42	246	590	12
458014	GS	3543	18.3	89	1.2	369	177	131	110	41	245	592	12
458015	GS	3569	19.3	90	2.2	374	173	137	108	41	249	589	13
458016	GS	3544	16.7	90	1.5	381	174	141	108	40	261	579	12
458017	GS	3689	18.7	85	1.8	377	173	132	109	43	253	582	12
458018	GS	3518	18.3	93	1.3	380	174	136	109	41	258	581	12
458019	GS	3624	18.3	88	1.7	365	180	133	109	42	266	572	11
458020	GS	3670	20.0	91	1.7	367	179	134	106	43	240	600	12
458021	GS	3689	19.3	91	2.0	373	173	130	106	40	252	591	12

Table C7. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458022	GS	3860	19.3	91	1.3	371	175	139	105	42	237	604	12
458023	GS	3643	17.7	89	1.5	368	177	129	107	43	245	594	12
458024	GS	3717	19.7	91	1.7	371	174	130	108	42	247	591	12
458025	GS	3797	19.7	93	1.7	374	176	153	106	44	248	591	11
458026	GS	3708	19.0	87	1.3	372	175	131	108	42	251	587	11
458027	GS	3589	19.3	79	1.0	364	178	115	107	41	217	623	12
458028	GR	3548	17.7	91	1.7	378	171	133	109	42	246	591	12
458029	GR	3558	17.3	82	1.2	375	168	118	109	42	230	607	13
458030	GR	3598	16.0	90	1.5	371	174	125	108	43	256	580	12
458031	GR	3470	16.7	83	1.5	377	170	128	108	43	251	586	13
458032	GR	3664	19.0	94	1.7	371	177	133	109	41	251	585	14
458033	GR	3324	17.3	87	1.3	383	167	134	107	42	252	586	12
458034	GR	3520	17.3	79	1.7	371	173	118	110	45	231	602	12
458035	GR	3744	17.3	91	1.8	375	170	128	107	43	253	585	12
458036	GR	3572	17.3	91	2.0	379	169	129	107	45	253	583	12
458037	GR	3555	19.0	99	1.7	384	169	144	109	41	260	578	12
458038	GR	3532	17.3	98	1.8	382	174	140	109	40	253	587	12
458039	GR	3504	16.3	91	1.5	381	174	144	110	41	264	571	12
458040	GR	3535	15.7	95	1.5	373	176	131	108	40	268	573	12
458041	GR	3489	18.7	97	1.8	383	172	145	108	39	253	587	12
458042	GR	3477	19.0	91	1.7	375	174	135	108	40	251	589	12
458043	GR	3435	18.3	90	1.7	376	174	128	107	43	239	599	12
458044	GR	3536	19.0	96	2.0	379	173	135	110	41	250	587	12
458045	GR	3563	19.3	91	1.5	378	174	136	110	38	260	580	12

Table C7. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
458046	GR	3726	18.3	95	1.5	365	178	134	107	42	255	585	12
458047	GR	3778	19.3	87	1.5	367	182	146	106	43	251	588	11
458048	GR	3798	18.7	95	1.7	366	180	134	107	46	253	582	11
458049	GR	3679	18.3	81	1.2	367	180	132	109	43	250	587	11
458050	GR	3661	18.7	91	1.8	368	179	132	108	44	245	592	11
458051	GR	3695	18.3	87	1.2	367	180	140	108	42	256	583	12
458052	GR	3835	19.3	90	1.2	373	175	137	110	43	222	614	12
458053	GR	3561	20.0	85	1.2	371	176	135	109	42	234	604	12
458054	GR	3643	18.7	89	1.7	365	183	137	107	42	248	591	12
458055	BC2-YT (GT)	3537	17.7	93	1.7	379	169		111	43	260	575	12
458056	BC2-YT (GT)	3519	19.3	94	1.7	380	173		108	42	258	580	12
458057	BC2-YT (GT)	3766	20.7	87	1.3	363	180		106	43	243	597	11
458058	BC2-YT (GT)	3530	19.0	87	1.7	373	177		107	42	252	588	11
458059	BC2-YT (GT)	3627	20.7	101	1.8	368	178		106	42	255	586	12
458060	BC2-YT (GT)	3634	20.0	91	1.3	371	177		104	44	252	588	12
458061	BC2-YT (GT)	3545	18.7	81	1.3	364	180		107	42	241	599	11
458062	IA2079 (GS)	3632	18.3	91	1.3	369	177	129	107	41	256	585	12
458063	IA2079 (GS)	3565	17.0	89	1.5	373	177		108	41	254	585	12
458064	IA2079 (GS)#	3634	17.3	91	1.7	370	177		107	43	248	591	12
458065	IA2079 (GS)#	3582	17.0	91	1.8	373	176		106	41	249	591	12
458066	BC3-bulk (GS)#	3436	20.3	96	1.7	374	174		107	40	229	612	12
458067	BC3-bulk (GS)#	3416	19.3	87	1.5	373	172		108	41	232	606	12
458068	CSR2252N (GT)	3590	16.3	87	1.0	360	184		106	39	218	564	74
458069	CSR2522N (GT)	3860	18.0	91	1.5	361	181		113	41	239	529	78

Table C7. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
458070	CSR2682N (GT)	3898	22.0	93	1.3	362	179		103	36	206	574	80
SEM††		89.0	0.5	4.2	0.2	1.8	1.0	3.4	1.4	1.1	6.0	6.2	0.4
LSD 0.05††		249.6	1.5	11.8	0.5	5.0	2.8	9.6	3.8	3.1	16.7	17.5	1.1
LSD 0.01††		330.1	2.0	15.7	0.7	6.6	3.8	12.7	5.1	4.1	22.1	23.1	1.5

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 458055 through 458070 were not included in this calculation.

Table C8. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA3028BC, the recurrent parent, and check entries grown in Ames, IA, in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days‡	cm	score§	g kg^{-1}¶	g kg^{-1}¶	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
459001	GS	3940	18.0	99	2.5	353	186	142	100	46	239	602	13
459002	GS	3749	18.0	84	1.8	361	182	128	107	48	238	595	13
459003	GS	3778	19.7	93	2.5	351	184	143	100	49	268	571	12
459004	GS	3870	19.3	87	2.2	358	183	139	101	50	244	593	13
459005	GS	3673	18.0	86	2.5	352	181	139	102	50	275	559	13
459006	GS	3460	16.0	93	2.5	360	183	134	107	50	234	596	13
459007	GS	3935	18.3	93	2.0	355	182	138	105	50	278	554	13
459008	GS	3759	18.7	81	1.8	358	179	136	100	47	259	581	13
459009	GS	3639	19.3	90	1.8	358	181	134	97	47	269	574	13
459010	GS	3928	18.3	96	2.5	358	178	118	100	47	216	624	13
459011	GS	3821	18.3	102	2.7	361	178	124	103	46	228	610	14
459012	GS	3850	21.3	91	2.5	363	176	125	102	47	235	603	14
459013	GS	3608	19.3	91	3.2	352	182	120	101	44	213	628	13
459014	GS	3587	17.3	86	2.0	363	180	124	107	46	254	580	13
459015	GS	3739	18.3	85	2.5	359	177	120	99	44	212	633	13
459016	GS	3659	18.0	86	2.7	362	176	119	105	41	198	643	13
459017	GS	3423	14.7	75	2.5	367	175	120	102	41	207	636	14
459018	GS	3624	19.0	87	1.8	349	183	124	100	43	228	618	12
459019	GS	4100	23.0	83	2.8	364	177	134	106	44	213	624	14
459020	GS	3550	19.7	99	2.7	366	178	127	101	48	237	601	13
459021	GS	3694	23.3	99	3.0	362	177	145	103	46	236	602	14

Table C8. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
459022	GS	2683	12.7	90	4.0	375	181	137	98	48	269	572	14
459023	GS	3354	21.0	95	3.3	360	179	132	105	48	239	595	14
459024	GS	3417	20.7	86	3.0	373	174	151	108	48	246	585	14
459025	GS	3430	20.7	92	3.3	364	179	140	105	46	220	616	13
459026	GS	3102	18.0	91	3.8	365	180	124	110	44	220	613	13
459027	GS	3150	16.7	87	3.2	364	181	135	109	46	234	597	13
459028	GR	3906	18.7	99	2.2	350	184	143	103	50	259	575	13
459029	GR	3839	18.3	97	2.7	351	183	132	106	49	235	598	13
459030	GR	3855	18.7	87	2.2	352	182	129	102	46	262	577	13
459031	GR	3767	18.0	92	2.2	349	186	142	105	48	257	577	13
459032	GR	3705	17.3	99	2.5	354	186	145	99	44	234	610	12
459033	GR	3845	20.7	93	2.5	348	183	141	97	43	234	612	13
459034	GR	3957	17.7	99	2.8	359	183	143	109	48	235	595	13
459035	GR	3767	20.7	99	2.7	352	183	147	107	51	268	561	13
459036	GR	3753	15.7	88	2.3	352	187	137	106	43	240	598	13
459037	GR	3546	17.7	95	2.5	367	175	132	104	47	225	612	13
459038	GR	3668	17.3	89	2.0	364	178	116	109	42	228	607	13
459039	GR	3757	17.7	92	2.8	357	176	121	97	43	235	613	13
459040	GR	3576	13.0	88	2.8	357	183	126	96	41	227	624	13
459041	GR	3370	18.3	90	2.7	357	180	123	105	44	229	608	14
459042	GR	3682	21.3	92	2.3	358	178	128	98	46	226	617	14
459043	GR	3598	17.3	93	2.7	356	183	129	100	48	239	600	13
459044	GR	3880	19.7	95	2.2	354	179	121	102	44	222	619	13
459045	GR	3590	20.0	97	2.8	365	175	122	99	42	220	625	13

Table C8. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
459046	GR	3440	18.7	93	2.8	369	180	126	106	46	223	612	13
459047	GR	3389	18.3	90	2.5	367	178	132	105	44	219	617	14
459048	GR	3745	21.0	110	2.8	369	177	142	106	46	224	610	14
459049	GR	3574	22.3	96	2.8	369	174	149	103	48	256	579	14
459050	GR	3593	20.7	89	3.5	360	182	136	104	43	213	626	14
459051	GR	3624	20.3	97	3.3	362	181	132	107	45	227	608	13
459052	GR	3621	19.3	102	2.5	366	179	134	110	47	243	586	14
459053	GR	3818	22.3	102	3.2	366	177	134	100	48	227	611	14
459054	GR	3616	21.7	97	2.8	370	178	134	102	45	226	611	14
459055	BC2-YT (GT)	4127	19.3	96	2.3	365	179		103	42	242	600	13
459056	BC2-YT (GT)	3664	18.3	81	1.8	354	189		105	46	239	598	13
459057	BC2-YT (GT)	3741	21.3	91	2.2	361	178		96	43	208	640	13
459058	BC2-YT (GT)	3478	19.0	99	2.8	369	174		102	43	221	621	13
459059	BC2-YT (GT)	3738	21.7	92	2.7	367	178		98	44	236	600	23
459060	BC2-YT (GT)	3637	23.0	99	3.5	363	178		110	46	214	615	14
459061	IA3028 (GS)	3748	18.3	89	2.3	359	180	130	101	45	231	609	13
459062	IA3028 (GS)	3650	18.7	87	2.8	361	178		101	42	229	615	13
459063	IA3028 (GS)#	3605	19.0	85	2.2	360	179		103	44	245	596	13
459064	IA3028 (GS)#	3489	18.3	83	2.8	357	181		102	47	243	593	14
459065	BC3-bulk (GT)#	3363	20.0	98	2.8	356	181		101	43	230	612	12
459066	BC3-bulk (GT)#	3548	19.7	97	2.8	355	181		100	45	232	611	13
459067	BC3-bulk (GT)#	3685	18.3	96	2.5	357	182		101	45	243	599	13
459068	CSR2522N (GT)	3499	15.0	87	1.7	349	189		113	43	231	540	73
459069	CSR2682N (GT)	3783	18.3	80	1.7	346	189		102	38	204	574	81

Table C8. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
459070	CSR3242N (GT)	4070	21.0	97	1.8	346	191		116	40	243	532	69
SEM††		162.2	0.7	4.2	0.3	2.2	1.2	3.6	1.3	2.2	10.3	11.3	0.4
LSD 0.05††		455.5	2.1	11.8	0.7	6.0	3.3	10.2	3.8	6.3	28.8	31.7	1.0
LSD 0.01††		603.2	2.7	15.6	1.0	8.0	4.3	13.5	5.0	8.3	38.2	41.5	1.4

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 459055 through 459070 were not included in this calculation.

Table C9. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA3028BC, the recurrent parent, and check entries grown in Carlisle, IA, in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days‡	cm	score§	g kg^{-1}¶	g kg^{-1}¶	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
459001	GS	3982	18.0	106	2.8	358	183	158	104	47	259	577	14
459002	GS	4325	14.7	93	2.5	362	182	145	108	43	271	566	12
459003	GS	4261	17.0	106	2.7	353	181	156	100	44	284	560	12
459004	GS	4021	16.3	103	2.2	360	182	146	103	45	266	574	13
459005	GS	4420	17.7	98	3.0	356	178	150	106	44	272	565	13
459006	GS	3895	15.2	99	2.8	363	181	138	109	44	228	606	13
459007	GS	4348	17.5	95	2.7	356	180	155	106	48	265	568	13
459008	GS	4699	16.7	95	2.2	361	180	152	103	44	264	565	13
459009	GS	4556	18.3	102	2.2	357	180	151	102	42	272	572	12
459010	GS	4302	16.0	95	2.7	352	180	124	104	44	235	604	13
459011	GS	4217	17.5	101	2.8	360	177	132	105	42	222	617	14
459012	GS	3966	18.5	91	3.0	360	175	133	108	41	210	628	14
459013	GS	4343	18.7	99	3.3	350	186	135	101	42	237	607	13
459014	GS	3434	15.2	97	2.5	361	182	136	106	44	269	567	15
459015	GS	4286	17.0	97	2.8	357	179	126	104	41	210	632	13
459016	GS	4129	15.3	93	3.2	357	180	124	106	41	208	631	13
459017	GS	4025	12.0	95	2.8	363	180	128	106	41	215	625	14
459018	GS	4225	17.5	95	2.3	355	182	138	107	41	220	615	13
459019	GS	4530	22.3	97	2.7	364	177	143	111	44	226	605	14
459020	GS	3736	19.3	101	3.8	373	176	136	106	42	230	608	14
459021	GS	3693	22.0	97	3.3	367	175	153	104	46	266	570	14

Table C9. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
459022	GS	3001	13.0	83	4.3	374	180	148	100	44	276	567	13
459023	GS	4184	22.3	97	3.7	359	179	136	111	44	247	584	13
459024	GS	3581	22.7	99	3.2	370	174	163	109	42	268	568	13
459025	GS	3356	22.3	94	3.8	363	178	157	109	43	233	603	13
459026	GS	3254	17.5	107	3.7	364	181	136	112	44	229	601	14
459027	GS	3550	15.8	93	4.2	361	182	144	112	42	233	598	14
459028	GR	4083	18.5	101	3.0	358	178	162	108	46	286	547	13
459029	GR	3709	18.0	95	3.8	355	181	150	111	44	238	595	12
459030	GR	3934	17.3	97	3.0	359	180	147	106	43	269	570	12
459031	GR	4472	17.0	101	3.5	357	183	157	106	46	279	556	13
459032	GR	4423	16.0	106	3.3	356	183	159	104	45	247	592	12
459033	GR	4107	18.7	101	3.0	350	183	153	102	43	263	579	13
459034	GR	4490	16.2	101	3.3	359	184	153	112	46	260	569	13
459035	GR	4587	18.0	109	2.8	357	180	167	108	41	274	565	13
459036	GR	4171	14.8	97	3.7	362	183	142	106	43	258	581	13
459037	GR	4056	15.8	99	2.8	361	179	131	105	42	216	624	13
459038	GR	4060	15.7	91	2.7	364	179	135	114	42	217	614	13
459039	GR	4099	15.2	99	3.3	356	182	132	101	43	253	590	13
459040	GR	3418	13.0	92	3.0	349	185	128	99	41	234	614	13
459041	GR	3465	15.5	91	3.2	353	179	122	108	39	218	622	13
459042	GR	4131	17.2	103	2.8	353	180	129	104	41	239	604	13
459043	GR	3683	16.2	95	3.3	360	182	134	105	41	235	606	13
459044	GR	4155	17.2	104	2.5	350	184	127	105	42	219	621	13
459045	GR	4111	19.2	98	2.7	363	179	125	102	44	242	601	13

Table C9. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
459046	GR	3960	18.3	94	3.7	367	182	136	107	45	261	574	13
459047	GR	3561	17.5	98	3.3	372	177	141	107	44	240	595	14
459048	GR	4071	21.7	106	3.0	364	178	158	110	45	229	602	14
459049	GR	3855	21.5	97	2.7	364	175	151	107	44	237	599	14
459050	GR	4115	23.0	104	3.3	356	184	135	104	43	243	597	13
459051	GR	3707	24.0	109	3.7	360	181	133	109	43	228	608	13
459052	GR	3850	18.0	101	3.7	367	181	141	113	46	247	581	13
459053	GR	3669	21.0	108	3.7	368	178	142	103	46	250	587	14
459054	GR	3658	25.0	102	3.5	365	182	144	102	41	233	611	13
459055	BC2-YT (GT)	4050	20.0	101	2.7	360	178		105	44	258	579	13
459056	BC2-YT (GT)	4374	17.3	95	3.5	358	187		106	46	250	586	12
459057	BC2-YT (GT)	4234	18.8	103	2.5	354	183		98	41	212	636	13
459058	BC2-YT (GT)	4176	17.2	105	2.7	364	175		105	40	229	613	13
459059	BC2-YT (GT)	4566	21.3	95	3.0	358	180		102	43	237	597	21
459060	BC2-YT (GT)	4006	21.7	109	3.2	360	179		111	45	253	576	14
459061	IA3028 (GS)	3909	16.0	103	3.2	361	181	136	103	42	232	611	13
459062	IA3028 (GS)	3776	16.3	92	3.7	360	180		103	45	256	583	13
459063	IA3028 (GS)#	4037	16.8	95	3.3	365	178		107	42	236	599	13
459064	IA3028 (GS)#	3522	16.7	95	3.5	362	178		104	41	243	599	13
459065	BC3-bulk (GT)#	3427	16.7	101	3.3	356	183		102	44	264	577	13
459066	BC3-bulk (GT)#	3704	16.8	105	3.2	355	184		104	41	232	610	13
459067	BC3-bulk (GT)#	3672	18.0	105	3.3	355	182		102	42	270	573	13
459068	CSR2522N (GT)	4178	14.7	88	1.8	355	188		117	44	244	522	73
459069	CSR2682N (GT)	4822	18.3	90	1.8	351	190		106	37	238	548	71

Table C9. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
459070	CSR3242N (GT)	4596	21.7	101	2.2	354	190		116	39	300	485	61
SEM††		206.6	0.8	3.6	0.2	2.0	1.1	3.1	1.5	1.5	8.8	9.1	1.2
LSD 0.05††		579.4	2.3	10.0	0.6	5.5	3.1	8.8	4.1	4.3	24.6	25.4	1.2
LSD 0.01††		766.6	3.0	13.3	0.8	7.2	4.1	12.0	5.4	5.7	32.5	33.6	1.6

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

Table C10. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA3028BC, the recurrent parent, and check entries grown in Rippey, IA, in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days‡	cm	score§	g kg^{-1}¶	g kg^{-1}¶	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
459001	GS	3544	18.7	95	1.2	349	184	138	101	46	239	600	13
459002	GS	3539	16.7	95	1.5	356	182	131	104	52	250	581	13
459003	GS	3540	20.7	97	1.5	348	184	135	102	48	246	591	13
459004	GS	3347	18.3	91	1.2	347	186	130	100	49	243	595	13
459005	GS	3504	17.7	91	1.7	352	179	130	107	50	256	574	13
459006	GS	3299	17.3	93	1.7	355	182	128	108	45	213	619	14
459007	GS	3546	17.0	93	1.5	352	182	135	107	52	254	574	14
459008	GS	3683	17.0	86	1.2	356	179	139	99	48	252	588	14
459009	GS	3680	19.0	93	1.3	354	181	132	98	53	295	542	13
459010	GS	3289	18.7	93	1.5	353	176	114	100	47	219	620	14
459011	GS	3141	19.0	97	1.7	358	177	120	101	46	215	623	14
459012	GS	3562	21.0	95	1.7	359	173	117	106	44	210	627	14
459013	GS	3383	19.3	93	1.3	345	183	117	98	46	228	614	13
459014	GS	3310	16.7	87	1.5	360	177	123	107	47	237	597	13
459015	GS	3182	18.0	90	1.5	354	175	114	102	42	204	640	13
459016	GS	3386	18.3	87	1.3	354	174	111	107	41	196	642	14
459017	GS	2946	14.0	80	1.0	363	173	118	104	43	208	632	13
459018	GS	3168	19.3	89	1.3	345	181	117	105	43	212	627	13
459019	GS	3192	23.0	89	1.2	360	175	128	107	47	219	613	14
459020	GS	3070	20.0	99	1.8	365	176	123	101	50	247	588	14
459021	GS	3333	23.7	102	2.0	357	177	141	101	50	247	589	14

Table C10. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
459022	GS	3014	15.0	95	1.8	372	177	144	99	47	266	574	14
459023	GS	3412	21.7	105	2.2	361	176	129	107	51	227	601	14
459024	GS	3398	22.0	95	1.7	367	174	156	107	50	251	579	14
459025	GS	3377	22.0	89	1.8	359	178	133	105	46	220	615	14
459026	GS	3227	19.3	105	2.2	363	179	121	107	44	216	619	14
459027	GS	3144	18.0	98	2.0	362	179	134	109	46	234	597	14
459028	GR	3549	19.0	96	1.5	349	182	139	101	51	288	548	12
459029	GR	3572	18.7	101	2.3	348	184	134	105	47	224	611	13
459030	GR	3325	17.7	95	1.5	355	180	136	102	52	274	560	13
459031	GR	3407	18.3	95	1.5	347	185	139	103	53	265	566	13
459032	GR	3496	18.3	107	2.3	348	186	144	99	48	248	592	13
459033	GR	3436	19.3	97	1.7	346	184	139	98	47	232	611	14
459034	GR	3456	17.0	95	1.7	351	184	130	106	47	234	600	13
459035	GR	3372	20.0	96	1.8	345	185	140	106	47	248	586	13
459036	GR	3531	15.7	99	1.8	351	185	143	108	46	222	611	13
459037	GR	3280	18.7	92	1.5	361	176	128	104	43	216	623	13
459038	GR	3383	17.7	93	1.3	356	177	125	110	42	206	628	14
459039	GR	3353	17.7	91	1.7	355	178	119	102	47	228	611	13
459040	GR	3025	14.3	84	1.0	346	182	123	96	42	213	635	14
459041	GR	2978	18.0	88	1.5	353	175	117	104	42	205	635	14
459042	GR	3176	20.7	93	1.7	351	177	130	100	47	233	606	14
459043	GR	3258	18.7	92	1.7	356	180	130	102	49	245	591	13
459044	GR	3342	20.0	101	1.7	350	180	121	103	45	217	622	13
459045	GR	3018	19.7	92	1.3	356	175	117	98	47	231	611	14

Table C10. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
459046	GR	3167	18.0	96	2.0	366	179	131	106	47	226	605	13
459047	GR	3134	19.3	94	1.8	365	177	137	105	46	231	604	14
459048	GR	3488	21.7	101	1.7	362	177	152	104	45	218	618	14
459049	GR	3447	21.0	98	2.0	362	174	142	102	50	254	579	14
459050	GR	3499	20.3	95	1.7	352	182	134	103	44	217	623	14
459051	GR	3133	19.3	104	2.2	361	179	134	104	50	231	601	14
459052	GR	3353	21.0	103	1.7	366	178	141	109	50	236	591	14
459053	GR	2917	24.3	100	1.8	359	177	138	102	50	241	592	14
459054	GR	3080	21.0	95	2.0	362	179	136	100	48	235	603	14
459055	BC2-YT (GT)	3536	20.0	100	2.0	359	179		103	49	243	591	14
459056	BC2-YT (GT)	3383	18.7	90	1.5	354	187		105	47	238	597	13
459057	BC2-YT (GT)	3311	20.0	91	1.5	353	180		99	44	213	631	14
459058	BC2-YT (GT)	3251	20.3	98	1.7	355	174		100	46	227	614	13
459059	BC2-YT (GT)	3415	25.3	97	1.7	357	179		97	45	237	603	18
459060	BC2-YT (GT)	3307	24.0	97	1.8	361	177		107	46	221	612	14
459061	IA3028 (GS)	3442	19.0	94	1.5	359	177	133	102	45	233	606	13
459062	IA3028 (GS)	2981	18.7	92	1.5	358	178		104	49	235	598	14
459063	IA3028 (GS)#	3378	19.0	92	1.5	360	177		102	48	232	605	14
459064	IA3028 (GS)#	3224	19.3	90	1.3	358	177		102	48	234	602	14
459065	BC3-bulk (GT)#	3311	19.7	98	1.7	356	181		101	44	220	622	13
459066	BC3-bulk (GT)#	3098	19.3	95	1.5	353	182		102	45	233	608	13
459067	BC3-bulk (GT)#	2938	20.7	93	1.3	350	184		99	48	233	607	13
459068	CSR2522N (GT)	2963	17.3	82	1.0	352	185		115	44	226	535	80
459069	CSR2682N (GT)	3487	20.3	85	1.0	352	182		103	38	201	577	81

Table C10. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
459070	CSR3242N (GT)	3338	25.7	92	1.5	351	190		118	42	243	528	70
SEM††		159.2	0.7	2.5	0.1	2.1	1.3	3.7	1.6	1.5	6.8	7.7	0.4
LSD 0.05††		446.4	1.9	6.9	0.4	5.8	3.8	10.3	4.4	4.3	19.2	21.7	1.0
LSD 0.01††		590.6	2.5	9.1	0.6	7.7	5.0	13.6	5.9	5.7	25.4	28.7	1.3

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 459055 through 459070 were not included in this calculation.

Table C11. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA3028BC, the recurrent parent, and check entries grown in Winterset, IA, in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days‡	cm	score§	g kg^{-1}¶	g kg^{-1}¶	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
459001	GS	3433	20.0	98	2.7	363	178	136	104	43	228	612	14
459002	GS	3299	19.0	89	2.2	374	170	124	109	41	218	618	14
459003	GS	3604	22.0	97	2.8	360	176	146	102	48	253	584	13
459004	GS	3554	20.7	92	2.7	365	175	134	104	44	230	608	13
459005	GS	3584	21.0	93	2.5	362	172	134	109	44	245	590	13
459006	GS	3439	20.0	102	2.3	368	174	126	112	42	213	620	13
459007	GS	3492	19.0	97	2.7	364	173	144	109	45	232	600	14
459008	GS	3475	19.0	95	2.0	365	173	137	103	42	250	591	15
459009	GS	3556	20.3	95	2.2	363	174	130	102	42	233	611	12
459010	GS	3463	21.3	95	2.2	368	169	118	102	43	217	625	14
459011	GS	3421	21.3	95	3.0	370	170	121	105	44	213	624	13
459012	GS	3297	22.7	88	2.7	373	165	120	107	42	206	630	14
459013	GS	3569	22.7	94	3.0	360	175	125	102	42	209	634	13
459014	GS	3467	19.0	89	2.2	370	172	123	106	45	246	589	14
459015	GS	3434	20.3	97	2.5	368	170	120	102	41	213	630	13
459016	GS	3556	20.7	83	2.2	369	167	117	111	43	199	634	14
459017	GS	3288	16.0	88	1.8	375	166	118	107	42	200	637	14
459018	GS	3500	23.3	97	2.2	366	173	118	102	40	216	629	13
459019	GS	3530	25.0	94	3.0	372	170	131	110	44	201	630	15
459020	GS	3327	22.7	102	3.2	377	170	123	103	44	230	608	14
459021	GS	3374	25.7	100	3.0	373	173	149	105	47	245	588	14

Table C11. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
459022	GS	3358	15.3	93	3.5	382	167	130	99	43	269	575	15
459023	GS	3339	25.0	106	3.3	370	173	133	108	46	227	605	14
459024	GS	3248	23.3	97	2.8	380	169	148	110	43	233	601	14
459025	GS	3372	24.0	93	3.2	374	173	142	109	45	213	620	14
459026	GS	3362	21.7	87	3.5	371	173	124	114	44	209	620	13
459027	GS	3319	19.3	89	3.2	377	168	131	110	41	217	618	15
459028	GR	3667	21.3	91	2.3	359	178	143	107	44	245	592	12
459029	GR	3545	22.0	93	3.0	361	175	138	109	45	228	606	13
459030	GR	3447	20.3	102	2.5	361	179	135	107	41	241	599	13
459031	GR	3533	21.0	101	2.7	358	178	139	106	45	253	584	14
459032	GR	3327	20.3	105	3.2	363	176	139	102	43	228	615	12
459033	GR	3405	22.3	90	2.8	358	175	137	100	43	227	618	13
459034	GR	3483	19.7	101	3.0	365	177	132	113	45	224	605	14
459035	GR	3684	23.7	97	2.8	358	177	141	108	44	241	590	13
459036	GR	3472	18.3	90	2.7	364	177	135	104	40	211	633	13
459037	GR	3368	20.0	90	2.2	376	166	125	105	42	212	627	13
459038	GR	3345	20.7	87	2.0	372	169	119	111	41	202	632	14
459039	GR	3610	20.7	89	2.5	367	167	129	98	44	225	619	14
459040	GR	3418	17.0	93	2.8	361	173	123	100	40	208	635	14
459041	GR	3298	21.0	91	2.8	369	169	115	109	40	226	612	14
459042	GR	3406	24.0	96	3.0	367	169	124	101	43	232	610	14
459043	GR	3329	19.7	89	2.2	370	173	133	105	42	210	630	13
459044	GR	3522	22.0	98	2.7	364	172	123	104	41	220	622	13
459045	GR	3296	22.7	95	2.5	370	169	117	101	44	225	617	13

Table C11. Continued

Entry	Type	Yield (kg ha^{-1})	Maturity (days)	Height (cm)	Lodging (score)	Protein (g kg^{-1})	Oil (g kg^{-1})	Seed Weight (mg sd^{-1})	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Oleate (g kg^{-1})	Linoleate (g kg^{-1})	Linolenate (g kg^{-1})
459046	GR	3342	20.0	103	2.8	376	175	125	108	44	218	617	14
459047	GR	3340	22.0	85	2.5	378	170	133	108	45	221	612	14
459048	GR	3269	24.0	97	3.0	371	171	146	109	45	217	615	14
459049	GR	3352	25.3	96	2.7	373	169	139	108	40	222	617	14
459050	GR	3362	24.0	103	3.3	366	179	133	105	42	212	626	14
459051	GR	3360	22.0	94	2.3	372	171	125	106	43	211	627	14
459052	GR	3388	21.3	100	2.7	376	172	143	114	44	219	609	14
459053	GR	3584	24.7	99	2.5	369	172	125	101	46	221	618	14
459054	GR	3434	23.3	98	3.3	376	171	132	103	44	223	615	14
459055	BC2-YT (GT)	3653	23.3	101	2.7	370	173		104	43	237	603	13
459056	BC2-YT (GT)	3432	20.7	95	2.5	366	180		107	41	219	620	13
459057	BC2-YT (GT)	3451	22.3	95	2.5	367	171		98	40	203	644	15
459058	BC2-YT (GT)	3644	22.7	99	3.0	376	166		101	41	211	634	14
459059	BC2-YT (GT)	3379	25.7	91	3.5	371	172		97	40	242	603	17
459060	BC2-YT (GT)	3357	25.3	96	3.2	372	172		109	45	226	606	13
459061	IA3028 (GS)	3429	19.3	101	2.7	369	171	125	103	42	231	611	14
459062	IA3028 (GS)	3536	21.7	95	2.7	366	174		103	45	227	612	13
459063	IA3028 (GS)#	3410	20.7	96	2.5	366	170		104	43	220	619	14
459064	IA3028 (GS)#	3370	21.3	94	2.5	367	172		102	45	218	621	14
459065	BC3-bulk (GT)#	3448	21.7	102	2.7	364	175		105	42	216	624	13
459066	BC3-bulk (GT)#	3395	22.7	98	2.3	362	175		100	42	226	615	17
459067	BC3-bulk (GT)#	3452	22.0	97	3.2	364	174		104	41	220	622	13
459068	CSR2522N (GT)	3776	18.0	90	1.5	366	178		113	41	236	532	78
459069	CSR2682N (GT)	3854	21.3	95	1.3	365	177		104	37	207	568	83

Table C11. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
459070	CSR3242N (GT)	3867	26.0	91	1.8	353	188		116	40	248	525	71
SEM††		73.7	0.7	3.8	0.3	1.3	1.2	3.7	1.2	1.3	6.9	7.5	0.3
LSD 0.05††		206.6	1.9	10.6	0.7	3.8	3.3	10.3	3.5	3.5	19.4	21.1	0.9
LSD 0.01††		273.4	2.5	14.0	1.0	5.0	4.4	13.6	4.6	4.7	25.7	27.9	1.2

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 459055 through 459070 were not included in this calculation.

Table C12. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA3041BC, the recurrent parent, and check entries grown in Ames, IA, in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days‡	cm	score§	g kg^{-1}¶	g kg^{-1}¶	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
460001	GS	3708	29.7	107	4.2	356	171	132	104	45	258	580	13
460002	GS	3922	28.7	94	3.7	351	175	135	107	38	256	587	13
460003	GS	3517	29.0	95	3.2	355	173	131	107	40	251	589	13
460004	GS	3686	26.3	95	3.3	348	179	131	110	42	238	598	13
460005	GS	3638	28.3	101	3.7	359	177	133	107	42	249	588	13
460006	GS	3769	28.3	95	2.7	349	176	132	107	42	240	599	13
460007	GS	3931	31.7	101	3.5	352	175	140	109	40	248	589	13
460008	GS	3689	29.3	104	3.2	353	176	141	109	41	241	597	13
460009	GS	3378	29.7	97	4.0	354	171	137	108	39	237	602	13
460010	GS	3596	30.7	93	3.0	342	172	132	107	42	230	608	13
460011	GS	3820	29.0	90	2.0	343	181	148	107	48	251	582	13
460012	GS	3825	30.3	95	2.8	345	174	147	109	42	228	608	13
460013	GS	3947	30.7	87	2.5	342	170	138	105	36	223	624	13
460014	GS	3609	28.0	93	2.2	354	173	142	108	37	238	604	13
460015	GS	4150	30.3	104	2.7	350	170	144	107	44	253	583	13
460016	GS	3989	29.3	105	3.2	347	172	146	106	40	232	608	13
460017	GS	3805	29.3	98	2.2	342	174	138	106	38	239	604	12
460018	GS	4085	31.3	97	3.0	349	176	146	108	45	250	585	13
460019	GS	3600	31.0	95	2.7	349	180	141	111	47	235	595	13
460020	GS	3693	30.3	108	3.2	348	173	147	106	43	236	602	14
460021	GS	3650	26.3	94	2.2	347	178	142	105	46	249	587	13

Table C12. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
460022	GS	3486	26.7	107	2.3	348	172	145	105	41	264	578	12
460023	GS	4013	26.3	95	2.5	346	175	144	106	41	248	593	13
460024	GS	3645	29.7	109	2.8	354	171	141	109	41	239	599	12
460025	GS	3550	30.3	108	3.0	344	174	139	109	44	236	598	13
460026	GS	3818	29.3	109	2.8	348	173	151	101	44	270	573	12
460027	GS	3491	29.3	92	2.3	350	172	144	110	44	239	593	13
460028	GR	3597	29.3	91	3.2	353	176	134	111	38	241	596	13
460029	GR	3390	28.3	93	4.2	348	176	121	108	43	230	607	13
460030	GR	3669	30.0	97	3.0	349	173	140	106	39	241	602	12
460031	GR	3945	29.0	101	2.8	348	175	133	108	39	236	605	13
460032	GR	3939	29.7	101	3.0	352	176	136	109	43	251	584	13
460033	GR	3446	30.7	91	3.7	351	177	144	107	42	252	586	13
460034	GR	3485	31.7	93	3.5	348	173	147	106	36	256	589	13
460035	GR	3299	27.0	99	2.7	350	175	139	110	44	238	595	14
460036	GR	3504	27.7	93	2.8	355	171	138	108	36	266	576	14
460037	GR	4330	30.3	97	2.8	347	173	146	106	38	227	618	12
460038	GR	3766	32.3	99	2.7	347	179	156	108	45	231	603	13
460039	GR	4018	29.3	100	2.0	353	175	141	103	37	280	567	13
460040	GR	3568	31.7	106	3.2	352	174	148	106	37	245	600	12
460041	GR	3820	31.7	101	3.0	351	172	157	107	42	250	588	13
460042	GR	4202	32.0	100	2.8	355	173	152	105	44	250	589	13
460043	GR	3810	31.3	103	2.8	348	177	149	105	46	245	592	12
460044	GR	4009	29.0	96	2.5	349	178	152	107	44	236	600	13
460045	GR	3954	28.7	105	3.0	352	172	143	103	37	247	599	13

Table C12. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
460046	GR	3712	30.0	102	2.8	349	177	148	104	47	267	570	13
460047	GR	3819	29.7	105	3.0	352	175	154	104	43	241	599	14
460048	GR	3777	27.7	99	3.0	349	173	143	106	42	241	599	13
460049	GR	3630	30.3	106	2.7	348	174	146	105	46	255	581	13
460050	GR	3651	28.7	97	2.5	342	170	144	105	40	247	595	13
460051	GR	3632	30.7	103	2.8	347	175	147	106	43	233	605	12
460052	GR	3996	29.0	102	2.7	350	178	153	109	41	238	599	12
460053	GR	3920	31.7	103	2.5	350	176	154	107	45	234	602	13
460054	GR	3844	27.0	97	1.8	344	171	147	101	39	248	599	13
460055	BC2-YT (GT)	3810	31	101	3.0	353	175		106	44	248	590	12
460056	BC2-YT (GT)	3972	29	101	2.7	347	180		109	45	241	592	13
460057	IA3041 (GS)	3935	30	95	2.7	348	178	141	105	38	244	602	12
460058	IA3041 (GS)	4269	28	95	2.7	346	180		106	41	266	574	12
460059	IA3041 (GS)#	3652	29	89	2.5	349	178		104	41	248	595	12
460060	IA3041 (GS)#	3846	29	93	2.2	347	176		106	42	253	587	13
460061	BC3-bulk (GT)#	3712	31	97	2.7	348	179		107	42	247	591	12
460062	BC3-bulk (GT)#	3942	31	99	2.7	350	178		104	43	245	596	12
460063	BC3-bulk (GT)#	3551	32	93	2.8	349	177		106	43	238	600	12
460064	BC3-bulk (GT)#	3720	30	96	2.7	351	178		104	45	243	596	13
460065	BC3-bulk (GT)#	3646	31	93	2.7	351	177		105	40	234	608	13
460066	BC3-bulk (GT)#	3636	31	93	2.7	352	177		106	42	253	587	12
460067	BC3-bulk (GT)#	3709	31	93	3.2	351	177		105	42	244	597	13
460068	CSR2952N (GT)	3736	23	89	2.0	345	182		112	41	219	550	79
460069	CSR3132N (GT)	4117	24	96	2.0	359	184		112	38	209	562	79

Table C12. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
460070	CSR3432N(GT)	3798	29	91	1.7	336	189		100	42	215	568	75
SEM††		204.1	0.9	4.2	0.3	2.5	1.3	4.0	1.3	1.5	9.1	9.6	0.4
LSD 0.05††		573.1	2.5	11.9	0.3	7.0	3.6	11.3	3.6	4.2	25.6	26.9	1.1
LSD 0.01††		759.0	3.3	15.8	1.2	9.3	4.8	15.0	4.8	5.6	33.9	35.6	1.5

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 460055 through 460070 were not included in this calculation.

Table C13. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA3041BC, the recurrent parent, and check entries grown in Carlisle, IA, in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days‡	cm	score§	g kg^{-1}¶	g kg^{-1}¶	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
460001	GS	3683	27.3	85	3.8	355	172	128	109	39	274	564	13
460002	GS	3712	24.3	88	3.5	345	173	122	110	39	246	591	14
460003	GS	3723	23.7	95	3.0	351	175	120	114	36	250	587	13
460004	GS	3946	24.0	99	3.8	346	175	122	114	41	256	575	14
460005	GS	3860	25.0	101	3.3	354	176	128	115	42	233	595	15
460006	GS	3732	25.0	101	3.0	347	177	128	114	39	228	605	13
460007	GS	3722	26.7	87	3.3	352	176	133	113	41	261	572	13
460008	GS	3887	25.0	99	3.0	348	178	142	114	37	242	593	14
460009	GS	3526	26.3	87	4.0	352	172	131	109	37	279	561	14
460010	GS	4164	26.0	91	2.2	345	169	130	114	38	243	592	13
460011	GS	4569	24.7	97	2.3	348	180	149	112	40	275	559	13
460012	GS	4200	25.7	95	2.5	344	176	146	113	41	238	595	13
460013	GS	4263	25.3	95	1.7	349	170	137	110	32	233	612	13
460014	GS	4613	24.7	105	2.5	356	177	141	116	38	239	593	13
460015	GS	4328	26.7	100	2.7	344	174	142	111	41	264	571	13
460016	GS	4365	25.7	99	2.7	341	179	143	111	39	238	598	14
460017	GS	4362	23.7	95	2.0	344	172	131	110	36	253	588	13
460018	GS	4617	24.7	96	2.7	348	179	141	113	44	247	584	13
460019	GS	4373	23.7	108	2.5	348	180	136	117	40	242	589	12
460020	GS	3980	24.7	95	2.8	347	175	141	115	41	244	587	13
460021	GS	4421	22.7	100	2.0	350	176	140	112	41	265	568	14

Table C13. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
460022	GS	4186	22.7	100	2.3	346	173	143	110	40	278	560	12
460023	GS	4353	22.3	105	2.7	345	176	141	111	39	255	582	13
460024	GS	4355	26.7	101	2.5	351	174	143	111	42	252	583	13
460025	GS	4146	24.0	101	2.7	342	177	131	112	41	239	595	14
460026	GS	4170	25.7	105	2.7	348	174	150	109	40	270	568	12
460027	GS	4222	23.3	101	2.3	354	172	142	117	40	231	600	14
460028	GR	3808	24.7	92	3.5	352	175	141	116	37	256	578	13
460029	GR	3307	25.7	100	4.0	347	177	116	117	38	219	611	15
460030	GR	4073	26.3	99	2.7	349	175	143	113	38	277	560	13
460031	GR	3785	25.0	98	3.2	347	178	130	115	39	242	591	13
460032	GR	4044	26.3	102	2.8	350	176	140	114	41	259	572	14
460033	GR	4128	24.7	99	3.2	350	181	142	112	39	270	566	13
460034	GR	4064	25.7	104	3.0	349	175	146	109	35	285	558	13
460035	GR	3827	24.3	91	3.0	350	174	139	116	39	241	590	14
460036	GR	3901	25.0	95	3.5	357	169	138	114	34	251	588	14
460037	GR	4438	24.0	97	2.2	348	173	141	113	38	241	595	13
460038	GR	5044	26.7	98	2.3	346	183	147	115	43	253	576	13
460039	GR	4438	24.3	104	2.0	352	177	152	110	34	250	592	14
460040	GR	4375	25.0	104	2.8	350	176	139	112	35	254	587	12
460041	GR	4311	23.7	101	2.0	348	173	141	113	40	250	583	13
460042	GR	4214	26.0	99	3.0	352	170	137	109	36	268	574	13
460043	GR	4290	25.7	96	2.7	348	181	152	114	41	252	581	12
460044	GR	4384	24.3	97	2.5	346	180	150	114	43	246	584	13
460045	GR	4095	24.7	102	2.5	349	172	145	109	36	255	586	14

Table C13. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
460046	GR	4112	25.3	117	2.8	348	179	146	111	41	243	593	13
460047	GR	4130	25.7	109	2.8	353	174	156	109	39	247	592	13
460048	GR	4671	23.3	107	2.8	346	175	146	108	39	269	571	13
460049	GR	4377	24.0	105	2.8	344	178	147	111	40	257	579	13
460050	GR	4465	24.3	105	3.0	345	173	140	111	38	241	598	13
460051	GR	4151	24.7	105	2.5	345	176	140	111	42	237	596	14
460052	GR	4340	24.0	105	2.3	346	177	144	112	41	252	582	13
460053	GR	4404	25.0	107	2.7	350	178	158	110	39	262	576	13
460054	GR	4591	23.7	101	2.2	347	173	147	110	38	257	583	12
460055	BC2-YT (GT)	4552	22.7	107	2.5	351	176		111	40	262	574	12
460056	BC2-YT (GT)	4441	23.0	103	2.7	344	184		115	45	263	565	13
460057	IA3041 (GS)	4323	24.3	98	2.2	349	179	138	117	40	249	581	13
460058	IA3041 (GS)	4524	25.0	93	2.3	349	179		113	39	253	582	13
460059	IA3041 (GS)#	4278	24.3	99	2.2	352	177		113	39	239	596	13
460060	IA3041 (GS)#	4222	25.0	96	2.3	352	180		112	39	251	584	14
460061	BC3-bulk (GT)#	4135	25.3	94	2.2	351	180		112	40	247	588	13
460062	BC3-bulk (GT)#	4126	26.0	103	3.0	350	178		113	40	255	580	13
460063	BC3-bulk (GT)#	4035	25.3	101	2.5	348	180		111	41	259	577	12
460064	BC3-bulk (GT)#	4447	25.3	99	2.3	352	179		112	41	246	588	13
460065	BC3-bulk (GT)#	4435	25.3	97	2.5	353	180		112	40	258	578	13
460066	BC3-bulk (GT)#	4113	24.7	93	2.3	352	178		113	38	266	569	14
460067	BC3-bulk (GT)#	3993	26.3	97	2.7	352	179		113	38	251	586	13
460068	CSR2952N (GT)	4227	18.3	103	2.0	353	181		116	39	235	538	71
460069	CSR3132N (GT)	3770	16.0	101	2.2	357	187		114	37	206	569	74

Table C13. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
460070	CSR3432N(GT)	4770	22.7	108	1.7	338	190		105	38	229	557	71
SEM††		182.7	0.6	3.4	0.2	1.7	1.0	3.2	1.1	1.4	8.7	8.6	0.4
LSD 0.05††		512.3	1.7	9.5	0.6	4.7	2.7	9.0	3.0	4.0	24.3	24.2	1.1
LSD 0.01††		677.7	2.2	12.5	0.7	6.3	3.6	11.8	4.0	5.3	32.2	32.1	1.5

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 460055 through 460070 were not included in this calculation.

Table C14. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA3041BC, the recurrent parent, and check entries grown in Rippey, IA, in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		$kg\ ha^{-1}$	days‡	cm	score§	$g\ kg^{-1}$¶	$g\ kg^{-1}$¶	$mg\ sd^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$
460001	GS	2961	31.0	101	2.8	351	170	128	104	42	235	606	14
460002	GS	3437	30.0	90	2.0	342	173	129	109	42	230	606	13
460003	GS	3108	29.3	94	1.8	340	174	123	108	38	224	617	13
460004	GS	3219	29.7	97	2.5	340	174	116	108	42	234	603	13
460005	GS	3327	29.0	99	2.0	346	178	125	108	43	238	598	13
460006	GS	3004	29.3	88	1.8	340	175	123	107	42	244	595	13
460007	GS	3364	30.7	107	2.5	342	177	135	111	42	259	575	13
460008	GS	3258	30.0	95	2.2	343	174	131	111	41	226	609	13
460009	GS	3316	29.7	100	3.2	349	169	130	112	42	234	597	14
460010	GS	3615	30.3	92	1.5	338	169	124	108	42	216	621	13
460011	GS	3398	30.7	99	1.5	333	181	137	106	46	232	604	14
460012	GS	3160	30.7	97	1.5	337	174	132	110	46	228	603	14
460013	GS	3068	31.3	87	1.2	336	168	130	108	36	220	622	13
460014	GS	3384	29.7	100	1.5	351	173	134	108	39	233	607	13
460015	GS	3018	30.7	97	1.7	337	173	131	108	46	232	602	13
460016	GS	3471	29.3	93	1.7	335	175	129	105	41	221	620	14
460017	GS	3028	29.3	90	1.2	334	173	127	107	40	220	620	13
460018	GS	3034	31.3	91	1.3	339	176	130	110	46	240	591	13
460019	GS	3082	29.3	97	1.3	341	180	128	113	45	227	602	13
460020	GS	3141	30.0	96	2.0	339	174	136	107	45	237	599	13
460021	GS	3374	28.7	101	1.2	344	176	135	108	45	246	588	13

Table C14. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
460022	GS	3254	29.7	105	1.3	345	170	142	106	42	257	583	12
460023	GS	3298	28.7	107	1.3	341	175	141	106	42	234	605	13
460024	GS	3071	30.7	99	1.3	340	174	127	109	45	233	600	13
460025	GS	3119	30.3	99	1.5	338	174	124	110	44	212	620	14
460026	GS	3130	31.0	105	1.8	345	171	143	104	43	244	596	13
460027	GS	3080	29.7	99	1.2	348	170	139	112	41	229	605	13
460028	GR	3427	28.7	99	1.8	346	175	139	113	40	225	609	13
460029	GR	3324	29.7	100	2.7	340	177	123	115	41	210	621	13
460030	GR	3128	30.0	95	1.7	335	176	133	109	41	251	586	12
460031	GR	3064	30.7	100	2.2	340	175	124	108	42	233	605	12
460032	GR	2955	30.0	99	1.8	343	178	124	112	44	248	583	13
460033	GR	3299	30.7	94	1.8	343	179	136	110	44	244	589	13
460034	GR	3047	30.3	95	1.7	342	174	134	108	37	242	601	13
460035	GR	3130	29.3	95	1.7	342	174	126	116	44	223	604	14
460036	GR	3003	29.7	100	2.2	349	170	132	110	38	237	602	14
460037	GR	3467	30.0	100	1.5	338	171	130	111	41	230	606	13
460038	GR	3202	30.7	95	1.3	335	181	136	110	46	238	592	13
460039	GR	3269	30.7	109	1.7	343	175	154	107	38	225	617	13
460040	GR	3289	30.7	95	1.5	340	176	133	106	40	237	604	13
460041	GR	3216	30.3	101	1.2	339	174	134	108	40	237	602	13
460042	GR	2993	31.3	101	1.7	345	169	149	106	42	241	599	13
460043	GR	3410	31.0	97	1.8	342	179	143	109	47	235	596	13
460044	GR	3441	30.3	103	1.8	340	176	138	109	44	239	595	12
460045	GR	3353	31.0	95	1.7	344	169	135	106	37	230	614	13

Table C14. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
460046	GR	2921	31.0	108	2.2	341	176	136	107	46	237	598	13
460047	GR	3175	30.3	105	2.2	344	174	145	104	43	247	594	13
460048	GR	2960	27.7	96	1.3	339	174	133	108	42	224	612	13
460049	GR	3303	29.3	111	1.8	343	175	140	107	43	240	598	13
460050	GR	2953	29.7	100	1.3	335	169	132	109	42	208	629	13
460051	GR	2935	30.3	102	1.5	340	173	130	106	44	232	606	12
460052	GR	3078	29.7	99	1.5	342	175	144	109	43	234	602	13
460053	GR	3168	30.0	102	1.5	344	174	146	107	46	237	597	13
460054	GR	2915	30.0	87	1.0	338	172	133	103	40	239	606	13
460055	BC2-YT (GT)	3235	29.0	110	1.3	350	174		107	46	251	584	13
460056	BC2-YT (GT)	3170	28.7	100	1.0	340	176		110	46	232	599	13
460057	IA3041 (GS)	3534	30.3	103	1.3	340	178	128	109	41	231	606	13
460058	IA3041 (GS)	3466	30.3	100	1.5	341	177		111	41	231	605	13
460059	IA3041 (GS)#	3417	29.7	99	1.7	339	179		107	42	232	607	13
460060	IA3041 (GS)#	3388	31.0	97	1.5	335	178		107	43	238	599	13
460061	BC3-bulk (GT)#	3267	31.3	100	1.7	341	178		110	42	236	600	12
460062	BC3-bulk (GT)#	3268	30.7	96	1.8	343	178		109	43	219	616	13
460063	BC3-bulk (GT)#	3521	30.7	97	2.0	343	179		106	41	238	602	12
460064	BC3-bulk (GT)#	3551	31.3	98	1.7	342	179		108	41	237	602	13
460065	BC3-bulk (GT)#	2860	30.3	90	1.8	337	178		109	42	238	598	13
460066	BC3-bulk (GT)#	3201	31.0	97	2.0	340	179		108	42	231	606	13
460067	BC3-bulk (GT)#	3051	31.3	99	1.8	336	176		110	43	230	605	13
460068	CSR2952N (GT)	3008	23.7	89	1.3	351	178		114	43	218	545	80
460069	CSR3132N (GT)	3347	25.3	87	1.0	361	179		111	38	196	576	79

Table C14. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
460070	CSR3432N(GT)	3064	30.0	100	1.3	334	189		102	42	213	567	77
SEM††		159.1	0.4	3.2	0.2	2.4	1.3	3.0	1.2	1.2	7.6	8.0	0.4
LSD 0.05††		446.2	1.2	9.0	0.7	6.7	3.6	8.4	3.3	3.4	21.2	22.3	1.0
LSD 0.01††		590.4	1.6	11.9	0.9	8.9	4.8	11.1	4.4	4.5	28.1	29.6	1.3

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 460055 through 460070 were not included in this calculation.

Table C15. Mean performance of 27 glyphosate-susceptible lines and 27 glyphosate-tolerant lines of IA3041BC, the recurrent parent, and check entries grown in Winterset, IA, in 2010.

Entry	Type†	Yield	Maturity	Height	Lodging	Protein	Oil	Seed weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days‡	cm	score§	g kg^{-1}¶	g kg^{-1}¶	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
460001	GS	3062	31.3	91	3.7	369	165	140	108	45	277	558	13
460002	GS	3194	30.7	82	2.7	359	166	132	109	40	246	593	13
460003	GS	3098	30.0	83	3.2	359	169	128	109	37	239	601	14
460004	GS	3082	29.7	94	2.8	358	168	131	110	41	241	595	13
460005	GS	3312	30.7	91	2.8	364	171	138	110	43	279	554	14
460006	GS	3135	30.3	93	3.3	360	170	138	111	40	247	590	12
460007	GS	3327	33.0	93	3.2	363	168	136	109	41	300	538	13
460008	GS	3305	30.3	89	3.2	363	169	140	109	39	244	594	13
460009	GS	3166	30.7	85	3.7	367	162	137	111	38	258	580	13
460010	GS	3391	33.3	88	2.0	353	166	131	107	41	258	582	13
460011	GS	3465	32.0	96	2.0	357	173	155	110	42	252	583	13
460012	GS	3307	32.0	91	2.0	359	168	148	110	41	259	576	13
460013	GS	3512	32.0	91	2.5	358	165	147	105	35	244	603	13
460014	GS	3329	29.7	89	1.7	372	168	143	109	37	252	588	14
460015	GS	3340	31.3	93	2.3	359	167	143	108	43	256	579	14
460016	GS	3193	31.7	90	2.3	358	168	143	108	41	263	575	13
460017	GS	3410	31.7	91	2.2	353	167	137	107	36	253	590	14
460018	GS	3473	31.7	93	2.7	355	172	144	112	44	282	550	13
460019	GS	3338	31.0	99	2.3	360	173	145	112	45	259	571	13
460020	GS	3395	31.0	101	2.7	355	171	155	108	41	273	565	13
460021	GS	3279	29.3	96	2.3	358	170	146	106	43	263	575	13

Table C15. Continued

Entry	Type	Yield kg ha^{-1}	Maturity days	Height cm	Lodging score	Protein g kg^{-1}	Oil g kg^{-1}	Seed Weight mg sd^{-1}	Palmitate g kg^{-1}	Stearate g kg^{-1}	Oleate g kg^{-1}	Linoleate g kg^{-1}	Linolenate g kg^{-1}
460022	GS	3344	30.0	97	2.0	358	166	150	105	41	273	568	13
460023	GS	3391	29.0	101	2.0	359	168	148	107	40	269	572	13
460024	GS	3422	31.7	99	2.2	360	168	143	109	44	251	583	13
460025	GS	3093	31.3	88	2.2	355	171	134	109	43	235	600	13
460026	GS	3297	31.3	98	2.3	363	164	148	106	40	269	572	13
460027	GS	3299	30.0	90	1.7	366	165	146	113	41	247	585	14
460028	GR	3401	29.3	89	3.0	364	168	134	110	39	260	578	13
460029	GR	3079	29.7	83	3.7	359	170	122	114	40	216	616	13
460030	GR	3333	31.7	93	2.3	361	167	138	109	38	273	566	13
460031	GR	3186	30.3	86	2.5	361	167	136	110	39	253	585	13
460032	GR	3244	32.0	97	2.8	364	169	142	112	42	287	547	12
460033	GR	3291	30.7	97	3.5	362	172	148	110	39	258	580	13
460034	GR	3344	30.3	90	3.2	360	168	144	106	34	261	586	13
460035	GR	3333	30.7	93	3.2	366	166	148	112	40	251	584	14
460036	GR	2967	29.7	85	3.3	370	162	136	110	35	253	588	14
460037	GR	3583	31.7	92	2.0	354	167	149	109	36	239	603	12
460038	GR	3508	32.0	93	2.2	357	173	153	110	44	273	560	13
460039	GR	3489	29.0	95	2.0	365	168	156	106	34	263	584	13
460040	GR	3500	31.3	92	2.3	362	168	142	109	37	248	593	13
460041	GR	3372	32.0	91	1.8	363	166	149	109	39	249	590	13
460042	GR	3507	32.3	96	2.2	364	163	144	109	39	253	586	13
460043	GR	3382	31.7	91	2.3	352	174	150	111	44	249	584	13
460044	GR	3341	30.7	93	2.0	356	170	150	109	44	262	573	13
460045	GR	3557	31.7	95	2.7	363	167	152	103	35	264	585	13

Table C15. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
460046	GR	3350	31.7	102	3.0	361	168	152	106	42	264	575	13
460047	GR	3239	31.3	94	2.2	362	167	151	105	40	272	571	12
460048	GR	3301	29.3	101	2.0	358	168	141	106	40	250	591	13
460049	GR	3251	31.0	103	2.2	356	170	148	109	44	275	560	13
460050	GR	3379	30.3	105	2.8	355	162	150	107	39	262	579	14
460051	GR	3383	32.0	101	2.5	355	171	148	108	40	255	585	12
460052	GR	3458	31.0	97	2.2	359	171	154	109	40	260	578	13
460053	GR	3422	31.3	92	2.3	361	169	154	106	42	285	554	13
460054	GR	3235	32.3	91	1.5	355	164	151	104	39	266	579	12
460055	BC2-YT (GT)	3429	30.3	106	2.7	363	170		106	39	262	580	14
460056	BC2-YT (GT)	3416	29.3	99	2.7	356	176		110	43	261	572	14
460057	IA3041 (GS)	3473	31.3	93	2.5	361	171	145	111	43	260	572	14
460058	IA3041 (GS)	3393	31.0	91	3.0	358	173		107	40	257	582	12
460059	IA3041 (GS)#	3539	32.0	93	2.2	359	170		107	39	254	586	13
460060	IA3041 (GS)#	3458	31.0	87	2.2	359	171		108	40	261	578	13
460061	BC3-bulk (GT)#	3384	31.7	90	2.3	359	173		107	42	278	561	12
460062	BC3-bulk (GT)#	3437	31.3	89	2.2	363	172		108	43	269	568	13
460063	BC3-bulk (GT)#	3436	32.7	89	2.5	360	173		105	41	255	587	13
460064	BC3-bulk (GT)#	3344	32.3	92	2.5	359	173		108	39	245	596	13
460065	BC3-bulk (GT)#	3484	31.0	91	2.7	361	172		106	40	262	580	13
460066	BC3-bulk (GT)#	3465	31.3	97	2.7	360	172		107	40	251	590	13
460067	BC3-bulk (GT)#	3371	32.3	96	2.2	361	173		109	41	277	560	13
460068	CSR2952N (GT)	3397	25.3	87	1.8	362	172		114	40	227	539	80
460069	CSR3132N (GT)	3358	26.0	91	1.7	370	176		112	38	210	561	80

Table C15. Continued

Entry	Type	Yield	Maturity	Height	Lodging	Protein	Oil	Seed Weight	Palmitate	Stearate	Oleate	Linoleate	Linolenate
		kg ha^{-1}	days	cm	score	g kg^{-1}	g kg^{-1}	mg sd^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
460070	CSR3432N(GT)	3532	30.3	98	1.8	346	182		104	42	213	560	81
SEM††		81.8	0.5	4.4	0.3	1.7	1.1	2.9	1.3	1.2	10.9	10.5	0.4
LSD 0.05††		229.2	1.3	12.4	0.8	4.8	3.1	8.2	3.6	3.4	30.5	29.5	1.0
LSD 0.01††		303.3	1.7	16.4	1.1	6.3	4.1	10.9	4.7	4.5	40.3	39.0	1.3

† GS = glyphosate-susceptible line, GT = glyphosate-tolerant line.

‡ Days after 31 August.

§ Scores ranged from 1 (all plants erect) to 5 (all plants prostrate).

¶ Protein and oil concentration on a moisture basis of 130 g kg^{-1}.

Seed for these entries was harvested in January 2010 in Puerto Rico, which was a different seed source then the rest of the entries in the experiment.

†† Entries 460055 through 460070 were not included in this calculation.

ACKNOWLEDGEMENTS

I would first and most importantly like to thank the Lord for the wonderful opportunity he gave me to pursue my graduate degree at Iowa State. By his power and grace I have learned lessons during difficult times and been able to see the beauty of his creation in all of my studies. He has blessed me with amazing gifts that I am thankful for every day. God has only begun to unveil his amazing plan for my life and has already surrounded me with a host of people that have given me support and guided me up to this point.

I would like to thank my wife Sara for all of her patience while I have been in graduate school. She has been a constant pillar of strength for me. She is always doing more than she needs to do to help me obtain my goals and many times doing it while under appreciated. My journey through my M.S. would have been more challenging and less enjoyable without her at my side.

I would also like to thank my parents for their constant love and support in everything I have done in my life. My father has been a constant role model who has always led by example and taught me the importance of hard work. My mother has always shown her love and taught me the importance of keeping God the center of everything I do.

I would like to thank Dr. Fehr for the constant patience and guidance he has given me during my time here. He has inspired in me a love for plant breeding that I never knew existed. I will always be able to think back onto my time at Iowa State and remember the many important lessons of breeding that he has taught me.

I would like to thank Susan Johnson and Grace Welke for their guidance, support, and lessons they have taught me. The enjoyable work atmosphere they invoked made every morning a pleasant day to come into work. I would like to thank Kevin Scholbrock for all of the hard work he did to make my research possible and the lessons of field maintenance he taught me. I would like to thank Dan Duvick for all of the fatty acid analyses work he did as part of my research.

Lastly, and very importantly, I would like to thank all of the graduate students that helped me during my time here. Especially Justin Mardorf and Ryan Brace whom I spent the majority of my time with for their constant insight into plant breeding and the laughs we shared during our time together. Also Shaylyn Wiarda, John Gill, Raechel Baumgartner, Loren Trimble, Sheila Oltmans-Deardorff, Jordan Spear, and Jonathan Jenkinson for all of the help they provided in class work and research. Also I would like to thank the countless number of interns who provided valuable help in my research.